# A DYNAMIC ECONOMETRIC MODEL
# OF
# THE U.S. SHRIMP MARKET

By

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Abstract of Dissertation Presented to the Graduate School
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By

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Department: Food and Resource Economics

Recently published statements relating to the fragility of traditional simultaneous equation econometric models cast doubt on the specification of existing models and therefore on the policies implied by the models. Concern over the impact inappropriate policies can have on societal welfare suggests that the specification of models that might likely be relied upon for policy development should be tested for misspecification. Since the goal of such action is the development of appropriate policy, the objective of a specific test is either to add to the creditability of the existing model or to use the information obtained from the test in an effort to develop a more appropriately specified model.

The simultaneous econometric model (SEM) testing and respecification process demonstrated here includes a test of the system-wide specification of an existing SEM that has been estimated with three stage least squares techniques. The misspecification test is a modification of the test suggested by Hausman. Here the difference between the unrestricted and restricted reduced forms implied by the structural model provide the data for the test. These data also provide clues to the sources of misspecification in the SEM being tested.

A vector autoregressive model (VAR) of the U.S. shrimp market is estimated as part of the effort to obtain information for the respecification of the SEM. Time and frequency domain analyses of the VAR model provide information useful for policy purposes; however, relatively little of the information is useful in respecifying the SEM. The policy implications of the VAR model and the existing and respecified SEMs are discussed. Also, the implications of existing data constraints on attempts to understand the U.S. shrimp market are discussed.

Although the existing SEM was found to be misspecified, its policy implications appear to be accurate. Analysis of the VAR model indicated that shrimp imports lead domestic prices in the short term but lag domestic prices over a three year period. This implies a significant amount of inertia in the current situation of increasing imports and decreasing domestic prices that has important implications for domestic and foreign policy makers and investors.

# CHAPTER I
# INTRODUCTION

## An Introduction to the U.S. Shrimp Market

The shrimp fishery is the most valuable of U.S. fisheries in terms of exvessel revenues and in terms of the value of processed products. In 1985, U.S. shrimp fishermen received approximately 473 million dollars for their products. For purposes of comparison, the next most valuable U.S. fishery in 1985 was the Pacific salmon fishery with landings worth approximately 440 million dollars, followed by the American lobster fishery with landings worth approximately 115 million dollars. Comparing the shrimp industry with other food industries is difficult due to the impacts it has over several states; however, it is interesting to note that Florida citrus growers received over 925 million dollars for their 1983 orange crop (Mulkey et al.). The value of all U.S. processed shrimp products in 1985 was approximately one billion dollars and represented approximately 20 percent of the total value of U.S. processed fishery products (USDCa, USDCb).

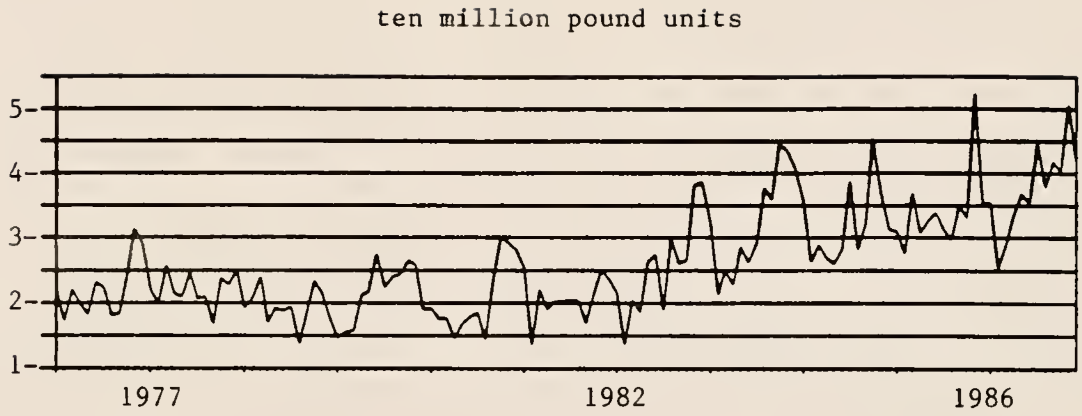
In addition to its importance to the national economy, the domestic shrimp industry is a major component of the economy in coastal communities of the Gulf and South Atlantic regions of the U.S. Griffin and Jones estimated the economic impact of the commercial shrimp catch on the Texas economy. According to their analysis, $1.00 of output by the shrimp industry required approximately $2.00 of output by supporting industries. A substantial portion of this support is directed toward the construction and maintenance of the fishing fleet. The Gulf and South Atlantic fleet has more than doubled in size from about 6,600 boats and vessels in 1950 to about 14,000 in 1983 (Vondruska).

This increase in fleet size has occurred while total landings from the area have grown less than 20 percent: Southern landings in 1960 were 149 million pounds, 142 million pounds in 1983, and 183 million pounds in 1985 (heads off basis). The average for the 1950-83 period was 143 million pounds. The average for the five-year period ending with 1985 was 165 million pounds (USDCa). A major reason the fleet has been able to expand in the face of such meager expansion in landings has been the increasing value of the catch. In real terms, the value of the 1983 catch, a year of reduced landings, was 3.3 times the value of the 1950 catch (Vondruska).

Shrimp are also landed in northern ports in the New England and the Pacific regions. In fact, most of the reported increases in total U.S. landings during the twenty year period between 1960 and 1980 were due to increases in these areas (Hu). However, U.S. landings outside the Gulf and South Atlantic region have remained fairly unimportant in terms of value and volume of landings. Over the five year period from 1980 to 1985, landings from the northern area accounted for less than 20 percent of total U.S. landings (USDCa). Additionally, the shrimp landed in northern ports are a different species from those landed in southern ports and are used for different purposes. Thus, the market for the warm water shrimp landed in southern ports can be analyzed separately from that dealing with the cold water shrimp of the north.

Perhaps, the most important feature of the U.S. shrimp market is its reliance on imported shrimp. Since the early 1960s imports have been the major source of shrimp consumed in the U.S. Since 1981 imports of shrimp have increased dramatically, reaching a peak in 1983 when they represented over 70 percent of U.S. supplies (Prochaska and Keithly). Imports have continued to increase every year since 1983; however, the proportion of total U.S. shrimp supplies accounted for by imported shrimp has declined, due to increased landings, to approximately 67 percent in 1986. Figure 1 displays the landings and imports data graphically. Also displayed are data on the real average monthly wholesale price of 26-30 count shrimp and data on expenditures in restaurants and other eating places. Because the U.S. and Japan are the major world markets for shrimp, imports into the U.S. are considered to be influenced by the relationship between the value of the U.S. dollar and Japanese yen (Prochaska and Keithly).

On a worldwide basis, stocks of naturally occurring shrimp are thought to be fully exploited (Rackowe). During the past decade, 1970-80, world shrimp catch increased over 50 percent; however, landings have remained relatively stable since 1977 (Rackowe). Environmental conditions are considered the primary cause of fluctuations in landings. The annual shrimp crop spends a critical stage of its development in estuarine waters where rainfall and water temperature can fluctuate widely on a year to year basis, causing large swings in survival rates among the growing shrimp.



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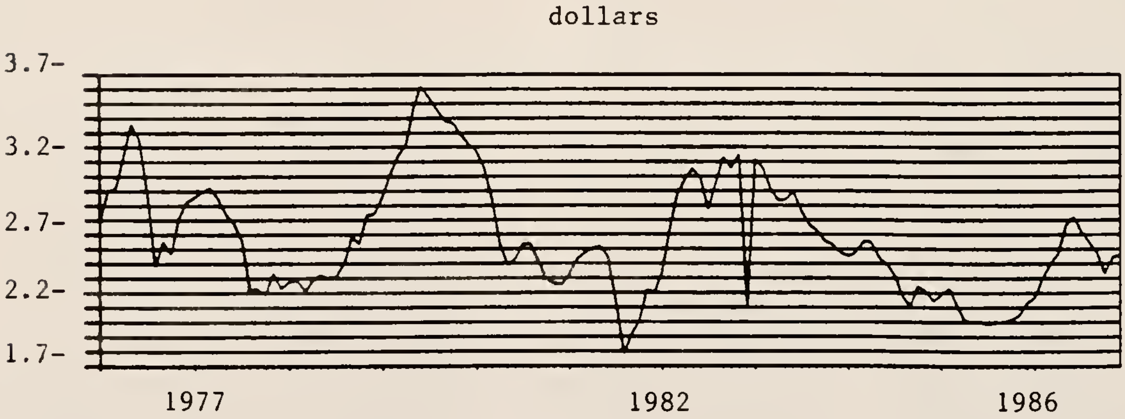

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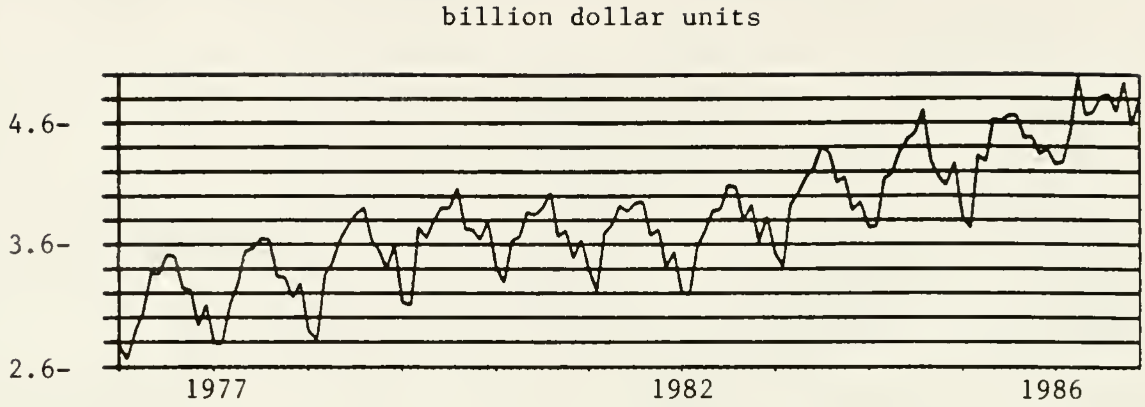
Figure 1-1. Selected U.S. Shrimp Market Data (source see Appendix F). a) Monthly Shrimp Imports into the U.S.; b) Monthly Average Real Wholesale Price of 26-30 Count Shrimp.; c) Monthly Expenditures in Eating Places.; d) Monthly Shrimp Landings in Gulf and South Atlantic Ports.



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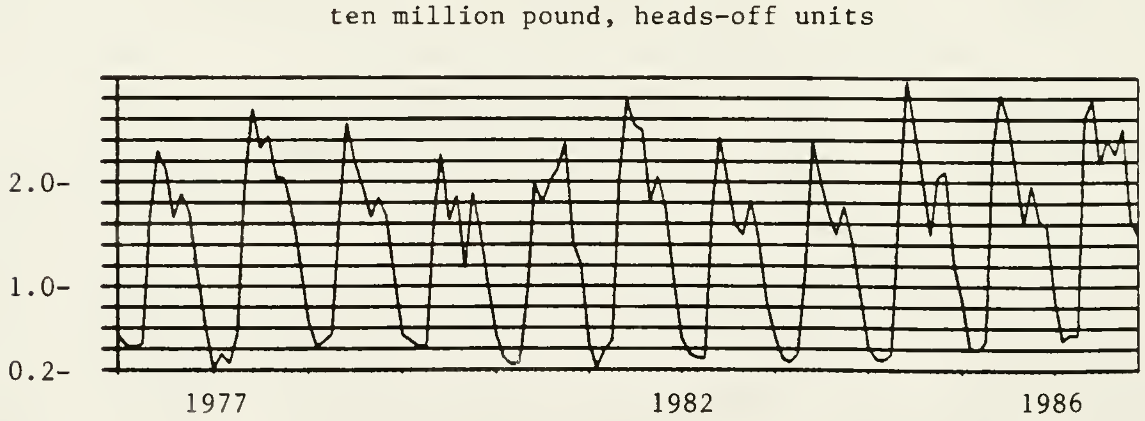

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Figure 1.1--continued

While U.S. landings have remained fairly stable since the 1950s, U.S. consumption of shrimp has grown significantly. The annual average rate of increase between 1950 and 1983 is 3.9 percent. In 1983, U.S. consumption was 3.5 times the 1950 level (Vondruska). Per capita consumption, however, has increased only about 2 percent per year over the twenty year period, 1966-85. The majority of this consumption, approximately 80 percent, has occurred in commercial eating establishments, generally termed "institutions," such as restaurants or governmental or company cafeterias. The fact that data on transactions in the institutional setting have not been collected on a systematic basis has had a major impact on economic analysis of the shrimp market. Because the essential data for demand analysis are not available, attempts to estimate the retail demand for shrimp in the U.S. may have produced misleading results.

The essential information for estimating the retail demand for a consumer product are data on the price paid by the consumer and the quantities purchased. Given the preponderance of transactions in the institutional setting, the relevant data for calculating the retail demand for shrimp and the related elasticities of demand are data from transactions in institutions. Unfortunately, prices of shrimp sold through retail outlets such as supermarkets and seafood markets are the only data available which relate directly to transactions with final consumers. These data series are not complete because their collection was discontinued in the early 1980s. The available data on the quantity of shrimp consumed in the U.S. are actually figures on movements of shrimp out of wholesale warehouses. An alternative term for this movement is "disappearances from cold storage".

Another implication of the large proportion of institutional sales is that shrimp demand is heavily dependent on the public's demand for food away from home. Thus, disposable income is expected to be a key determinant of shrimp demand (Rackowe).

## Problem Statement

With world shrimp catch levels near their expected maximum and with reasonable expectations that the demand for shrimp will continue to strengthen, a scenario that includes rising shrimp prices and increased congestion on U.S. shrimping grounds is not unreasonable. However, during the early 1980s, the technology of shrimp production was substantially transformed by the perfection of commercial-scale shrimp mariculture that is ostensibly independent of critical inputs from the natural environment.

Accordingly, the limits to the production of shrimp have been expanded from that of a natural production system to that of controlled production systems similar to those used to produce swine or poultry. Shrimp are now being reared from breeding stock to maturity in the highlands of Colorado (Brannon, 1986). The use of this technology under the more favorable biological and economic conditions existing outside the U.S.A. implies that the limits to production are those imposed by public policy and the market. The ramifications for the domestic U.S. shrimp fishery are immediately obvious.

In the absence of trade barriers, it is expected that increased supplies of maricultured shrimp will flow into the U.S. market until the marginal value (price) received by foreign producers is just equal to their marginal cost of production and distribution. To the extent that maricultured shrimp are less costly to produce than domestically captured shrimp and in the absence of sufficient shifts in U.S. demand for shrimp, these increased supplies will have a depressing effect on the prices U.S. producers receive for shrimp.

Because the U.S. shrimp fishery is considered to be a fully developed and possibly over-capitalized, purely competitive industry, any decrease in shrimp prices can be expected to force some U.S. fishermen out of business. Policy makers may be called upon to devise programs that will assist U.S. citizens to adjust to these changing conditions. These policies should be based on accurate predictions of the likely changes that will occur in the U.S. shrimp market due to the changed volume of imported shrimp.

Recent studies of the U.S. shrimp sector have contributed substantially to the understanding of the industry. However, the development of complete mathematical models of the industry useful for predicting price changes has been severely hampered by the absence of required data series and by limitations of previous modeling techniques to capture many of the complexities of the market. The absence of ideal data series may have resulted in erroneous conclusions about such policy variables as the price elasticity of demand or the income elasticity of demand. One purpose of this paper is to focus attention on this deficiency and its implications.

Examples of market complexities include rational expectations behavior, inventory behavior, price determination behavior, disequilibrium in product or factor markets, and pricing dynamics. One suggested method of treating such complexities is the vector autoregressive specification (Sims). Thus, a second purpose of this paper is to investigate the utility of the vector autoregressive specification in understanding the U.S. shrimp market.

The difficulty of modelling the complex behavioral relationships in an economic process such as a market may have resulted in the misspecification of economic models of the U.S. shrimp market. Indeed economic model misspecification appears to be "more likely the rule rather than the exception" (Judge et al., p. 854). Misspecification has been cited as a major reason model results and policy implications vary between studies (Prochaska and Keithly, p. 1; Adams, p. 3). These considerations have important implications since policies based on misspecified models may be inappropriate.

A concern for the impacts which policy can have on societal welfare suggests that the responsible action to take is to test the specification of models that might likely be relied on for policy purposes. The goal of such action is the development of appropriate policy. The objective of a specific test is either to add to the creditability of an existing model or to utilize the information contained in the model and the information obtained from a test of its specification in an effort to develop a more accurately specified model for policy making purposes.

Technological development in the production of shrimp has allowed an unprecedented increase in actual and potential imports of shrimp into the U.S. market which has the potential for causing substantial dislocation in the highly competitive U.S. production subsector and substantial changes in the U.S. marketing subsector. Because policies developed to address this situation will quite likely be based on existing econometric models, the U.S. shrimp market is an appropriate subject for the demonstration of the econometric model testing and respecification procedure briefly described above.

## Research Objectives

The major goal of this research is to develop, for use in policy making, a more complete understanding of the underlying behavioral relationships in the U.S. shrimp market. A secondary goal is to demonstrate two econometric techniques, viz., the vector autoregressive model and a simultaneous equation model specification test, that may prove to be useful additions to the analytical process of understanding markets in general.

The primary objective of this research is to develop a dynamic, econometric model of the U.S. shrimp market which can be judged as being properly specified by specification criteria to be discussed in the study. In accomplishing this objective, the two identified deficiencies of previous models will be addressed. A vector autoregressive specification of the market will be investigated for its usefulness in understanding the relations between variables of interest, for its usefulness as a predicting instrument, and for its usefulness in suggesting alterations to the structural econometric model which treat complex behavioral relationships not addressed by existing economic theory.

The lack of ideal data will be addressed by recognizing that the existing data may not be appropriate for estimating retail level relationships. Instead, the data will be used to estimate relationships at the wholesale market level which generated the data.

The primary objective will be accomplished by first testing the specification of an existing econometric model of the market. Next a vector autoregressive model of the market will be specified, estimated, and analyzed. The information gained from these analyses will be used to specify a dynamic structural econometric model. The model will then be tested for misspecification, and its forecast performance will be compared with the vector autoregressive model. Finally, the policy implications of the analyses will be discussed.

The specific objectives of this study are

a. to test the system-wide specification of an existing econometric model of the U.S. shrimp market;

b. to construct a vector autoregressive model of the U.S. shrimp market;

c. to determine point estimates for the temporal relationships between wholesale shrimp prices, U.S. shrimp landings, and import shrimp quantities, and construct confidence intervals for these estimates.

d. to specify and test the specification of a traditional econometric model, using the results from objectives a, b, and c;

e. to compare the out-of-sample forecast performance of the vector autoregressive and the structural models;

f. to discuss the policy implications of the models and other information developed.

## Research Approach

Testing the specification of an existing structural model of the U.S. shrimp market should provide an initial base of information useful for further analysis. A specification test based on Hausman's 1978 work is developed and applied. The difference between the estimated parameters of the restricted and unrestricted reduced forms implied by the structural model provide the basic data for the test. The difference between the two reduced forms also provides information on possible sources of misspecification. Similarly, the specification of the shrimp market in vector autoregressive form contributes additional information that is useful in respecifying the traditional simultaneous econometric model (SEM).

The specification of the vector autoregressive (VAR) model will be based on knowledge of the U.S. shrimp industry, likely concerns of policy makers, and economic theory. The degree of lags used in specifying the VAR are selected by a process of increasing the number of lags employed until tests of the hypothesis that the parameters of the additional set of lagged variables in the system are equal to zero cannot be rejected (Nickelsburg). This test is executed in the context of least squares estimation procedures since, in this case where each equation in the system contains identical regressors, least squares estimation is equivalent to maximum likelihood estimation (conditional on initial values of the regressors being treated as fixed). Since the number of lags specified will be the same for each equation, pretesting will be limited to system-wide specification.

Once the order of the VAR has been selected, the model will be reestimated in a restricted form reflecting theoretical judgement relating to the exogeneity of the variables in the endogenous system. The model will then be subjected to a diagnostic test to determine the distributional characteristics of the error terms in the system. If the vector of variables and the associated lag structure have been selected appropriately, the error terms should be random processes. The degree to which they approach this definition will be tested using Hosking's portmanteau statistic (Hosking). If the hypothesis of serially correlated residuals cannot be rejected, the addition of variables to the model or some transformation of existing variables may be indicated.

Once the vector autoregressive system has been specified, the relationships among variables of interest will be obtained by decomposing the parameter matrix of the system, using analyses in the frequency and time domains. Confidence intervals for these estimated relationships will be constructed via numerical differentiation.

The implications of the vector autoregressive model, along with information gained from testing the specification of the existing structural model, will be used in specifying a dynamic structural model (herein called the "respecified" model to distinguish it from the previously existing model of Thompson et al., which is referred to as the "existing" model). The respecified model will be tested using the same methodology previously demonstrated in the test of the existing structural model. Finally, the structural and vector autoregressive models will be compared and the implications for policy discussed.

## The Application of the Results of This Study

### Scientific Merit

The scientific merit of this study arises from the demonstration of a model specification test which can be easily adopted as part of the econometric model development procedure of other analysts. To the extent the use of this procedure results in more appropriately specified econometric models and more appropriate policy, society in general will benefit. Additional scientific merit and practical utility derives from the demonstration, as a part of the testing and respecification process, of a vector autoregressive specification of the phenomenon under study.

### Policy Applications

Potential users of the results of this study include domestic and foreign investors, foreign governments, domestic state and federal fishery regulatory agencies, and domestic and international trade regulatory agencies.

The policy issues that can be addressed using the results of this study include the advisability of a program to assist the U.S. shrimp production sector to adjust to the projected, continued decrease in real (adjusted for inflation) shrimp prices and the possible, concomitant reduction in operating shrimping vessels. The results of the vector autoregressive analysis should be helpful in understanding the likely delay in the industry's response to policy and price changes.

Such an understanding should be helpful in the development of appropriate policy. For example, given the impact of increased shrimp supplies on shrimp prices and an indication of the delay in the industry's response to price changes, domestic and foreign investors may need to adjust their estimates of expected prices used in analyzing investments in additional productive capacity. The domestic marketing sector should find these results helpful in forming expectations of the likely increase in shrimp supply and in planning investments to market the increase.

## Preview of the Remaining Chapters

The following chapter reviews the literature relating to existing studies of the shrimp market. The third chapter addresses the problem of using existing data to estimate retail level relationships and discusses other methodological considerations. The fourth and fifth chapters discuss the methodology used in applying the misspecification test and in specifying the vector autoregressive model and in analyzing the dynamic relationships among the variables in the VAR. The sixth chapter discusses the estimation of the VAR and its results. The seventh chapter discusses the reestimation of the structural econometric model and its estimated parameters. The final chapter compares the existing and the respecified SEM results, discusses the policy implications of the VAR and SEM models and discusses the benefits of the demonstrated approach to the development of appropriately specified simultaneous equation models.

# CHAPTER II
# REVIEW OF LITERATURE

A highly valued industry is allotted a corresponding degree of interest from public officials. This interest often results in the collection of data that makes econometric analysis possible. Accordingly, the U.S. shrimp industry has been the subject of a substantial amount of analysis. Naturally, one would expect the progression of methodologies employed over the years to reflect the developments in economic theory, in statistics, and in computing capability that have generally proceeded their application in applied economics. One would expect that the analysts conducting new studies have attempted to employ the most advanced techniques at their disposal in their attempt to add to the common body of knowledge. This process has tended to increase this stock of knowledge, although perhaps not uniformly over time.

Twenty years ago, most econometric models developed to analyze the demand for shrimp were single-equation functions. Nash and Bell catalogued the "best specimen" demand functions selected, from those available in 1968, by a panel of marine economists. The demand functions selected for shrimp were generally linear, single equation models estimated with least squares techniques. Three of the seven selected equations related to the wholesale market level, two related to the exvessel market level, and two to the retail level. The price elasticities of demand for shrimp calculated from these models ranged from -.78 to +.38 with four out of the six ranging from -.29 to -.46. The two retail price elasticity estimates were +.38 and -.28. Thus, none of the selected models estimated shrimp demand to be price elastic at the selected market level. The income elasticity estimates were all in the elastic range, i.e., greater than one, and ranged from 1.14 to 1.329 (Nash and Bell, p. 22-26).

The next phase of model development appears to have been that of multi-equation models. See for example, Timmer; Gillespie et al.; Doll; Batie; and Hopkins et al. Having been published in the American Journal of Agricultural Economics, the study by Doll is, perhaps, the most widely known of this group. In discussing his five-equation simultaneous equation model based on annual data, Doll first deals with the major problem confronting all researchers in this area: the lack of data on key variables in a theoretically specified model. Doll briefly describes what variables an ideal model would contain and then states: "However, when the ideal model was confronted with the realities of available data, some compromises became necessary" (p. 432).

One of those compromises involves imports as a source of shrimp to the U.S. market. Although Doll recognizes that foreign suppliers have a choice of marketing areas and that some U.S. importers buy on forward contracts, Doll is forced to treat imports as an exogenous variable, due to the lack of data. For a similar reason, Doll enters domestic landings of shrimp into his model as an exogenous variable. Doll questions this exogeneity, noting that landings increased during each recessionary period included in the time span under study. These two compromises lend credence to the statement by Sims that analysts often define a variable as exogenous because any serious effort to model the variable would take the researcher too far afield from his main area of interest. Another compromise is the recursive nature of the model. Doll does not attempt to justify this specification.

Continuing with the results reported by Doll, he shows that, as of 1968, domestic landings were the single largest source of price variation in the U.S. shrimp industry. Increases in U.S. disposable income kept a constant upward pressure on shrimp prices that would have increased prices by .08 cents per pound per year. However, increased import levels resulted in an average annual decrease in prices of .05 cents per pound that partially offset the price increases due to income growth.

Doll reports, with some caveats as to his confidence in the estimates, the income elasticity of shrimp at the retail level to be 1.12 and estimated own price demand elasticity at the retail level to be -.63. Doll notes that although the consumption of shrimp by individuals would be expected to be more responsive to retail price, such a result might be obscured in analyses, such as his, which do not have data on the majority of market transactions involving final consumers.

> The institutional demand for shrimp comprises an important part of the final market, and the cost of preparation and other services would be an important determinant of the price of the prepared food. Consumption under these conditions would not be responsive to changes in price alone. (Doll, p. 435)

The next generation of shrimp market models may be considered those that have gone afield of the model builder's main area of interest and have attempted to model those variables that previously had been recognized as being endogenous but were treated as exogenous through some compromise. Also, the dynamic relationships between variables are given some recognition through the use of lagged variables. Timmer incorporates an import supply function while still regarding domestic landings as exogenous. Batie successfully estimated a domestic supply function for the 1958-69 period using an index of Gulf of Mexico water temperatures to capture the biological fluctuations in shrimp populations. Both Hopkins et al. and Thompson et al. model domestic landings and imports.

Hopkins et al. develop an annual model of domestic supply as a function of wholesale prices of shrimp lagged one year, Gulf and South Atlantic landings of shrimp lagged one year, an index of vessel operating costs lagged one year and average monthly Mississippi River discharge for February through April. Import supply is modeled as a function of U.S. exvessel price lagged one year and imports lagged one year. Price dependent demand at the wholesale level is modeled as a function of beginning stocks, imports, and landings of shrimp. Although Hopkins et al. expected an inverse relationship between quantity supplied and price, they found a positive relationship between imports and U.S. wholesale price. The authors explained that the unexpected positive sign may reflect a supply response to general market conditions. The authors also commented that the positive sign contradicts harvesters' complaint that imports have a depressant effect on price (Hopkins et al., p. 8).

Beginning stocks of shrimp were found to have the largest direct impact (negative as expected) on wholesale prices. Yet, beginning stocks are a function of imports, most of which enter the U.S. during the last quarter of the year (Hopkins et al., p. 8). It is also valuable to note that the researchers found that the import supply equation is primarily a time trend with lagged imports playing the dominant role in the determination of current imports. As for elasticities, Hopkins et al. report an income elasticity of 1.65 and an own price elasticity of -.27.

Thompson et al. model domestic landings as a function of fishing effort, average precipitation in coastal Louisiana lagged two months, average atmospheric temperature in coastal Louisiana lagged two months, and quarterly dummy variables. Fishing effort is a function of the current exvessel price of shrimp, the current quantity landed, the price of diesel fuel, and seasonal dummy variables. The import quantity variable is modeled as a function of the wholesale price of shrimp lagged two months, the rate of exchange between U.S. dollars and the Japanese yen lagged two months, and seasonal dummy variables.

Thompson et al. suggest that studies of the U.S. shrimp market using data collected prior to recent structural changes in the market may be dated and, therefore, estimate a simultaneous system model using monthly data from September 1974 through December 1983. The authors recognize the difficulty of estimating the retail demand for shrimp when the existing data relate to the wholesale level. It is difficult to decide whether they consider the demand they are estimating to be at the retail level or at the wholesale level.

In discussing their demand equation, they apparently consider it a retail demand function because they mention that "economic theory suggests that the prices of substitute and complementary products be included in equation 1" (p. 13). Equation 1 is their consumption equation. They also mention the results of adding the price index for processed meat as an explanatory variable in the equation. In the reported version of their model these variables were not included because the authors found the variables to be insignificant in trial runs. The attempted inclusion of the processed meat variable could be interpreted to imply they consider the equation representative of derived wholesale-level demand, if the processed meat could be considered an input in a shrimp product. This consideration seems unlikely, impling that they consider the equation to be representative of retail demand. It appears that Thompson et al. have attempted to estimate retail demand using wholesale-level data.

Thompson et al. estimate the price elasticity of their demand function to be inelastic at -.11. They obtain an estimate of income elasticity of demand that contradicts that of most other research. The Thompson et al. estimate is in the inelastic range, viz -.42, which is indicative of an inferior good. The authors explain this discrepancy by noting that the elasticities from previous research were calculated from models estimated with data from the late 1950s to early 1970s: a period when shrimp consumption was increasing.

> A portion of the correlation between consumption and income during the period that previous studies dealt with can be attributed to their common correlation with time. From 1974 to 1982 shrimp consumption remained relatively stable. During the period consumption and income were no longer correlated with time. Estimates of income elasticity for the

> period would more closely approximate the actual income elasticity of demand. A recent study by Hu (1983) using annual data from 1960 through 1980 found an income elasticity of demand for shrimp of 0.73. The estimated elasticity of less than one can probably be attributed to the inclusion of several years of data after the early 1970's. With income a determinant of expenditures at retail eating establishments and 70-80 percent of shrimp consumption occurring at these sites, the use of income may overstate the size of the elasticity. (Thompson et al., p. 16)

The Thompson et al. estimate is actually the elasticity of consumption given a change in expenditures in retail eating places. Thus, the comparison between estimates is difficult. The expenditures variable is used as a proxy for income by the authors. However, an alternative definition for the variable is possible. Since no quantity data accompany the expenditures data, it is impossible to determine if changes in expenditures are the result of changes in quantity sold, changes in price, or some combination of changes in quantity and price. If the major change had been in quantity, the use of expenditures as a proxy for income is plausible. If the major change had been in price, the use of expenditures as a proxy for price becomes plausible. Under the alternative interpretation that retail expenditures in eating places may be considered a proxy for output price, the Thompson et al. model might be expected to predict price elasticity rather than income elasticity. In this case, the Thompson et al. estimate is consistent with the majority of estimates of price elasticity.

The most recent innovation in shrimp market modeling efforts is the utilization of causality measures by Adams to assist in specifying dynamic economic models for two size classes of shrimp. The approach taken is to identify the stochastic properties of the price series to be included in the model and then use these stochastic characteristics to test hypotheses regarding lead/lag structures and the direction of price determination between interfacing market levels. Finally, the dynamic properties of price determination and the structural attributes of the market, as suggested by theory, are incorporated into an econometric model describing price at each market level.

Specifically, the causality tests are used to specify a model based on monthly data in a recursive form while a simultaneous form is dictated for a model based on quarterly data. Theoretical considerations determined what nonprice variables, such as income, quantities, and consumer price index, would enter each of the structural equations. These nonprice variables enter the equations in an unlagged or current form. The causality testing procedures, their related impulse response functions, and certain diagnostic checks dictate which of the price variables and their specific degree of lag enter the structural equations.

Adams's results relating to income elasticity support those of Thompson et al.:

> Real disposable income was found to not be a significant determinant of monthly or quarterly prices for either size class. This finding reflects the fact that real disposable income changes very little on a monthly or quarterly basis over the time period of the analysis. Previous monthly and quarterly analyses corroborate the insignificance of income while studies using annual data typically find income as significant. (Adams, p. 165)

The price flexibilities of demand derived from final form coefficients are quite inelastic, i.e., less than |.5|, for both size classes (see Adams, Table 12, p. 144). These figures imply an elastic relationship between price and quantity demanded in the long run. In general, most variables had the anticipated relationship with the dependent variable of their related, price dependent demand equations. However, there was one exception involving one category of imports termed: all other imports. This variable had a positive relationship with the dependent variable of both size classes of shrimp under study. Adams found that beginning inventories has a larger effect on both classes of shrimp prices than does any class of imports or domestic landings. This effect is in accord with the findings of Hopkins et al. Also in accord with Hopkins et al., Adams found that total imports of shrimp are positively related to price. Income, in Adams's monthly or quarterly models, is not a significant determinant of price dependent demand.

# CHAPTER III
# METHODOLOGICAL CONSIDERATIONS

Economists strive to develop their models on strong theoretical foundations; however, limitations of the economic theory, research resource constraints, and the availability of data can often lead to model misspecifications which reduce the utility of the model. This chapter will discuss the implications of these three constraints on the present and past efforts to better understand the U.S. shrimp market.

## Data Constraints

The major data constraint, mentioned above, is the lack of information on quantities and prices of shrimp sold to final consumers through institutional markets. Although approximately 80 percent of U.S. shrimp consumption occurs in these commercial eating places, no price and quantity data on these transactions are systematically collected. As a result, researchers are forced to use available data from sales in retail outlets, which accounts for only 20 percent of shrimp consumption, to represent the primary market data (Adams, pp. 11, 175; Thompson et al., p. 12). Alternatively, analysts may chose to estimate retail level relationships using prices and quantities from the wholesale level.

### Some Policy Implications of Inadequate Data

Neither of these two approaches may be appropriate if the data used are not adequate proxies for the desired data. If the data, say from the wholesale level, are not adequate proxies for the retail level data, then the relationships found may more accurately describe the wholesale level rather than the retail level. Using wholesale level relationships in lieu of the desired retail relationships in the development of policy can lead to inappropriate policies.

As an example, consider a situation in which an industry can be characterized by constant returns to scale and fixed proportions. Layard and Walters's (p. 260-276) illustration of Marshall's rules relating to the influences governing the price elasticity of demand for a factor of production is helpful in this context. Given a fixed-proportion production function and perfect competition in the factor market, Layard and Walters show that the price elasticity of demand for a factor is equal to its share in the cost of the product being produced times the elasticity of demand for the final product. Mathematically,

$$\epsilon = \nu\eta, \text{ where}$$

$\epsilon$ is the price elasticity of demand for the factor, e.g., shrimp; $\nu$ is the share of the factor in the cost of the final product; and $\eta$ is the price elasticity of demand for the final product, e.g., a shrimp entree in a restaurant.

In the absence of adequate data on the retail market, the above relationship might be used to obtain an indication of the price elasticity of demand for the final product. As long as $\nu < |\epsilon|$, the price elasticity of demand for the final product is elastic. This may quite likely be the case relating to shrimp and the final products produced from shrimp. The share of food costs in restaurant sales varies from about 34 to 41 percent (National Restaurant Association).

Obviously, the shrimp in a shrimp dish is less than 100 percent of the related food cost. Thus, 34-41 percent represent the upper bound of the proportion of restaurant sales accounted for by shrimp. Thus, as long as the wholesale level price elasticity of demand for shrimp is greater, in absolute value, than 41 percent (approximately) it may be that the retail level price elasticity of demand for shrimp products is elastic.

The implication that the demand for shrimp is elastic is not consistent with the findings of most previous studies of the shrimp market. However, such a possibility provides some explanation for the contra-intuitive results of those previous studies. Recall the comments of Doll, quoted in the literature review, that one would expect consumers to be responsive to retail price.

### The Adequacy of the Available Data as Proxies for the Desired Data

Since the required data do not exist, attempts to estimate the retail demand for shrimp and its associated elasticities must rely on proxies for the desired data. Thus, the veracity of such estimates can be addressed through a consideration of the suitability of the existing data as appropriate proxies for the desired data. Attention is focused on the use of retail food market shrimp prices (retail prices) as proxies for the desired but unavailable prices of shrimp in institutions (institutional prices). The argument that retail prices are not good proxies for the institutional prices is based on a consideration of the probable production processes associated with the products produced in the two markets and the notion that shrimp purchased in retail outlets for home consumption and shrimp purchased in institutions for immediate consumption are two distinct products.

A difference in production processes argues against the existence of a high degree of correlation between two product prices. Following the analysis of Gardner, assume that the production processes in the two markets can be represented by the following production functions

$$R = f(s,a) \text{ and } I = f(s,b),$$

where R and I are the quantities produced in the retail and institutional markets, s is the input of shrimp into the processes, and a and b are bundles of marketing inputs specific to their associated processes. Gardner shows how the ratio of a retail level price to a farm level price can change differentially according to the source of a shock to the market. For example, Gardner derives the elasticity of the retail/farm price ratio with respect to a shift in demand for the retail product as

$$E_{Pr/Pf} = N_r S_b (e_s - e_b)/D,$$

where N is the price elasticity of demand for the retail product, $S_b$ is the relative share of input b in the price of the retail product, $e_s$ and $e_b$ are the elasticities of supply of the inputs, and D is a function of N, $e_s$, $e_b$, $S_s$, and the elasticity of substitution between the two inputs.

Now, for the price in the retail market, $P_r$, to be highly correlated with the price in the institutional market, $P_i$, $E_{Pr/Ps} = N_r S_a (e_s - e_a)/D$ will be highly correlated with $E_{Pi/Ps} = N_i S_b (e_s - e_b)/D$, This appears unlikely since it is probable that $N_r \neq N_i$, $S_a \neq S_b$, $e_a \neq e_b$, and that the elasticities of substitution between the two inputs are different in the two processes.

The elasticity of substitution between the two inputs in the retail market may be much closer to zero (see Heien) than in the institutional market where the institutional operator may have considerable control over the composition of the final product. The retail market operator is relatively more restricted in the types and amounts of marketing services it can add to the shrimp it sells. Heien demonstrates that markup pricing behavior is predictable for food retailers. Conversely, the nature of the institutional product allows it to be combined with a wider range of variable inputs such as other food ingredients or labor than can the retail product. This implies that $e_a \neq e_b$. If the retail product and the institutional product are in fact two distinct products, it can be assumed that $N_r \neq N_i$. Thus, if it can be shown that the two products are different, it appears improbable that their prices are highly correlated and are therefore not good proxies, one for the other.

## Empirical Evidence Relating to the Inadequacy of Available Proxies

Some empirical evidence exists which lends credence to the notion that the two products are distinct. Nash, in a study of purchasing patterns for fresh and frozen seafood, found that income had a more pronounced effect on consumption of seafood away from home than it had on at-home consumption. The age of the head of the household was also found to have a significant effect on away-from-home seafood consumption. These findings may indicate that the two groups of people, those that consume seafood at home and those that consume seafood in institutions, are different. Assuming both groups have access to both products, the finding that they tend to consume either one or the other of the product forms can imply that the two product forms represent two distinct products. Given a difference in consuming groups and a difference in products, it is plausible to assume that one demand relationship may not be an adequate representative of the other.

Keithly, in a study of the socioeconomic determinants of at home seafood consumption, found that expenditures on meals consumed away from home were negatively related to home consumption of total seafood and all product forms with the exception of shellfish which had an insignificant, positive parameter. Assuming that some of any increase in away from home food expenditures are for seafood, this finding may imply that seafood consumed at home and seafood consumed away from home are substitute products.

Evidence of a more general nature that food for home consumption and food consumed away from home represent two distinct products is found in the work of Mincer. Mincer demonstrated that estimated income elasticities for a variety of commodities will tend to be biased if the opportunity cost of time is omitted. Evidence of a similar vein is found in the works of Hiemstra and Eklund and in that of Burk. Their work suggests that the income elasticity of expenditures for food away from home is considerably higher and perhaps twice as high as the elasticity for at home food consumption expenditures (Prochaska and Schrimper). Apparently, the addition of preparation services so transforms the basic food commodity that a different product emerges as evidenced by the difference in demand for the two products.

## Implications of Inadequate Data for Previous Studies

A further implication of the use of wholesale level data as a proxy for retail data involves the prices of complements or substitutes expected to be included in a demand function. Several previous authors have noted their inability (see Thompson et al., p. 13) to demonstrate significant effects of complementary or substitute products on the demand for shrimp. The lack of correct data series may explain these empirical problems.

The proper explanatory variables for use in an input demand function are prices of inputs and outputs (McFadden, p. 74). The theory of retail demand holds that retail demand is a function of the price of the product, income, and the prices of all other products (complements or substitutes). An attempt to identify complementary or substitution effects implies the analysts consider the function they are estimating to be a retail demand function. If the existing data, e.g., the U.S. shrimp consumption data, are not adequate proxies for the correct data, this fact may explain why the expected relationships are not obtained. It may indicate that previous attempts to estimate the retail demand for shrimp or attempts to estimate the wholesale level derived demand which do not include the theoretically correct explanatory variables should be viewed with caution.

An example of an attempt to estimate the retail level demand is the work of Doll, who used retail food outlet price data and U.S. shrimp consumption (which is wholesale level data) to explain the retail demand for shrimp. Doll could not demonstrate any complementary or substitution effects. Hopkins et al. attempt to find a significant effect on the consumer price index for meat, poultry, and fish in a demand equation which employed wholesale prices and the standard wholesale level consumption figures. Since the consumer price index should, theoretically, be an argument in a retail level demand equation while the other two variables belong in a wholesale level derived demand equation, it should not be remarkable that the consumer price index variable was found to be insignificant.

A similar problem was noted by Thompson et al., who included the producers price index for processed meat as a price for shrimp substitutes in their (apparent) estimation of retail level shrimp consumption, yet employed wholesale level prices and wholesale level consumption in the analysis. If the wholesale level data are not adequate proxies for retail or institutional level data, their use in a demand estimation process would only be appropriate in the estimation of derived demand. The fact that complementary and substitute retail level products are not considered appropriate arguments in derived demand functions may explain why previous authors have experienced problems demonstrating complementary or substitution effects in their demand equations.

In light of these considerations, it appears unlikely that the retail market price of shrimp is an adequate proxy for the institutional market price because the two product forms are probably two distinct products with relatively distinct markets and production technologies. Further, it appears that previous efforts to estimate the retail level demand for shrimp using wholesale level data should be considered estimates of the wholesale level relationships. Therefore, without information on the prices and actual quantities of shrimp sold through institutions, it seems appropriate to consider any estimate of the retail demand for shrimp and any associated elasticities as being only rough approximations of the actual values. Furthermore, with the discontinuance of the collection of retail prices and the probable difficulty of imputing a price for shrimp in the institutional market (given its diverse technology), it appears that the calculation of retail demand estimates for shrimp in the U.S. has become virtually impossible. Thus, the model developed here will focus on the wholesale market level.

## Research Resource Constraints

The practical limits imposed by research project resource constraints can also lead to expediencies that cause misspecification. For example, variables that could be considered endogenous have been entered into economic models as exogenous variables due to inadequate information available to the analyst (cf. Thompson et al.) or, as Sims has observed, "because seriously explaining them would require an extensive modeling effort in areas away from the main interests of the model builders" (pp. 5, 6).

## Theoretical Constraints

An increasing understanding of the complexities of economic processes, reflected in the work of Muth (1960, 1961); Nerlove (1967); Lucas; and Pierce; has increased economists' appreciation of the difficulty of properly specifying many economic models and has revealed the limitations of the theory to provide complete guidance in these efforts. An obvious example is the inability of the theory to prescribe the proper number of lags or leads of variables in a dynamic econometric model (Nerlove, 1972). Attempts to account for known complexities have created additional problems. For example, Sims notes that including expectations variables in an econometric model may create identification problems. Perhaps the most disconcerting critique of standard econometric models is contained in a recent econometrics text by Judge et al. The authors note "that the possibilities for model misspecification are numerous and false statistical models are most likely the rule rather than the exception" (Judge et al., p. 854).

## Policy Implications of Misspecification

These critiques have significant relevance in the present context relating to the economic impact of increasing U.S. shrimp imports and the likelihood that existing econometric models will be used in the development of policy to address this situation. Policies based on misspecified models may be inappropriate. For example, the advisability of placing some restriction on the flow of shrimp into the U.S. is linked to the demand for shrimp.

Some economists, e.g., Prochaska and Keithly, suggest the income elasticity of shrimp demand is high enough that, when combined with a reasonable growth rate in U.S. disposable income and in the expected growth rate in aquacultured shrimp supplies, no barrier will be necessary to prevent a decline in the level of real shrimp prices. The implications of the research of other economists are that trade barriers may be required. For example, Thompson et al. have obtained estimates of the income elasticity of shrimp demand that are inelastic, indicating that shrimp can be considered an inferior good. Coupled with price inelasticity and increased supply, an income elasticity in the inelastic range implies that barriers to entry may be necessary to prevent a decline in shrimp prices, since growth in income cannot be expected to shift demand sufficiently to offset the depressive effects on price of increased supplies.

## Implications for the Present Effort

To the extent that these contradictory implications are the result of misspecification of the econometric models used, a test of system-wide specification may be useful in selecting a model as the basis of policy formation. Given the potential adverse impacts of inappropriate policy, it appears appropriate to encourage the testing of the specification of any model used for policy development. Finally, if the development of more accurate models of the shrimp market is to proceed from the base of existing knowledge contributed by current models, it would be helpful if some analysis of an existing model would reveal those portions of the model most appropriate for inclusion into a respecification.

Thus, it appears that an effort to develop a more accurate understanding of an economic process, such as the operation of a market, should begin with such a review of existing work and proceed with an investigation of the value of newer techniques to add to the existing stock of knowledge on the subject. The newly acquired knowledge can then be used in an attempt to respecify the traditional econometric model of the market in a manner that will allow it to be judged as being properly specified. Such an iterative approach to model development follows the suggestion of Zellner and Palm (p. 17): "we believe that testing the implications of structural assumptions for transfer functions and, we add, final equations is an important element in the process of iterating in on a model that is reasonably in accord with the information in the sample data."

An obvious next step in the evolution of shrimp market models is to generalize the dynamic model used by Adams by allowing all right-hand side variables to enter the model in appropriate degrees of lag. For example, lagged quantities may have a significant effect on current quantities and, thereby, on current price. This relationship seems especially relevant since such a large portion of shrimp flow through institutions. Institutions can be expected to have an established capacity to market an expected quantity of a given product that may fluctuate around some trend. The trend can be seen as the result of the adjustment process followed by individual firms as they respond to changes in their operating environment.

One method of capturing the influence of this adjustment process on a variable of interest is to add lags of the variable to the predicting equations as Adams does. However, such a procedure may be inadequate. Any method of modelling partial adjustment processes assumes, explicitly or implicitly, a theory of expectation formation (see Gould). As Maccini has pointed out, schemes that relate expected variables solely to past values of the variable being forecast have been widely criticized because they assume that the firm "ignores all pertinent information other than the past history of the forecasted variable in forming predictions" (p. 24). In a study using aggregate

U.S. business data, Maccini found that firms tend to utilize "economically rational" expectations in making forecasts. "Economically rational" implies that the firm depends on other relevant variables, such as shifts in government policy or other exogenous changes in the economic environment, in addition to lags of the variable being predicted, to form expectations. These expectations, in turn, affect adjustment rates.

At the level of a single industry, such as addressed in this study, the notion of "economically rational" expectations may imply that lags of variables other than the endogenous variable may be useful in explaining the endogenous variable in a given equation. Obvious candidates are lags of variables that appear in unlagged form. Thus, this study seeks to expand on previous efforts by allowing a more generous expression of lagged variables in what should be considered a respecification of existing models of the U.S. shrimp industry.

Given the acknowledged difficulties faced in the specification of a traditional econometric model, it is possible that an alternative, data-based approach to model specification may be a useful addition to the specification process. In particular, an initial vector autoregressive specification (VAR) of the economic phenomenon under study may be useful since, as argued by Sims, the VAR can accommodate the above mentioned modeling complexities to a considerable extent.

Additionally, since a VAR model can be seen as the unrestricted reduced form of a generalized econometric model, its parameter estimates, estimated with ordinary least squares techniques, are consistent with the economic processes which generated the sample data. To a large extent, this feature of the VAR model frees the analysis from the constraint of any particular theory relating to the operation of the economic phenomena under study and allows the sample data to speak for themselves.

The suggestion to employ such data-based techniques and the current interest in such techniques may derive additional impetus from the apparent fact that advances in computational capability have exceeded advances in obtaining successful empirical models based on economic theory. The current interest in data-based modeling techniques may also be encouraged by a recognition among economists that the formulation, identification, and estimation of dynamic econometric models must be approached in substantially new and different ways (Sargent, p. 216). This study seeks to follow the spirit of this search for an integrated approach to economic model development in an attempt to understand more fully the operation of the U.S. shrimp market.

# CHAPTER IV
# MISSPECIFICATION TEST

The value of an econometric model estimated with two stage least squares (2SLS) or three stage least squares (3SLS) procedures is contingent on a number of conditions (Theil, pp. 511-513), two of which being that all structural equations are correctly specified and are linear in the parameters and variables. Although methods exist to handle nonlinearities, such estimates exhibit a reduced level of efficiency, when compared to maximum likelihood estimators, unless the specification is linear in variables. Proper specification is particularly important in a 3SLS analysis since misspecification in a single equation is transmitted or "spread" across the entire system by the 3SLS process (Judge et al., p. 617).

Unfortunately, the probability of the correct specification being used appears to be quite low. An additional factor in support of this belief is that misspecification tests of econometric models have not been widely used. This failure to examine system-wide specification could, in the past, have been due to the lack of necessary statistical software and computing power. Thus, it is probable that the results of a test of the specification of an existing econometric model will indicate the model is misspecified. Note that the term "misspecification" is appropriate since the test used here searches for ways in which the existing specification is inadequate rather than searching for an alternative specification (see Kennedy, p. 67).

The purpose of testing an existing model of the U.S. shrimp market at the present time is to demonstrate a specification test procedure that can be more widely applied and to understand the strengths and weaknesses of the existing model so that this knowledge can be included in a respecification of the model.

In analyzing an existing econometric model, some specification tests may be impractical. For example, without detailed knowledge of existing data resources, it may be impossible to question the use of particular regressors. Thus, in the following analysis the list of endogenous and predetermined variables is not questioned, implying that the results of the analysis are contingent on the validity of the list selected by the original analysts. Additionally, the functional form of the existing model must be taken as given, since any alteration in the original specification would constitute a respecification of the model. Thus, the principle source of testable misspecification, once the list of endogenous and predetermined variables and functional form have been selected, is the set of exclusion restrictions placed on the model's parameters by the analysts.

The set of exclusion restrictions placed on the structural model will imply restrictions on the derived or restricted reduced form of the structural model. The veracity of these analyst-imposed restrictions can be tested by comparing the restricted reduced form with the unrestricted reduced form of the same model. Because the unrestricted reduced form is a system of equations with identical, predetermined regressors, the use of ordinary least squares (OLS) estimation techniques results in maximum likelihood estimates of the parameter values consistent with the population parameter values (Schmidt, p. 78).

Since the unrestricted reduced form is not influenced by the exclusion restrictions, the consistency of the reduced form estimates will not be dependent on the model specification. This result is not without some cost, as Dhrymes (p. 127) has shown that the unrestricted reduced form estimators are asymptotically inefficient in comparison with 3SLS reduced form estimators developed from a correctly specified econometric model. The problem associated with the 3SLS estimator is that all structural parameter estimates, and thus, their derived reduced form representation, will be inconsistent if any of the structural equations are misspecified (Challen and Hagger, p. 134).

## Hausman Test

The relationships between the restricted and unrestricted reduced form estimators motivate the use of the Hausman test (Hausman) in the present analysis. The test is based on the existence of two estimators of a vector of statistics, viz., the vector of parameter values of a simultaneous equation system's reduced form. Under the null hypothesis of no misspecification of the model, one of the estimators, here, the restricted reduced form parameter estimates derived from a 3SLS estimation of the structural parameters, is asymptotically consistent and efficient. Under the alternative hypothesis, this estimator is biased and inconsistent. The second estimator, here, the OLS estimate of the unrestricted reduced form, is consistent but comparatively inefficient under both hypotheses. If the null hypothesis is correct, both estimators will be similar in value. However, if the model is misspecified, the two estimators will be dissimilar in value. Thus, the difference between the two provides the data for the specification test.

Let $q = \mathrm{Vec}(\pi_o) - \mathrm{Vec}(\pi_3)$ be the difference between the two estimates, $\pi_o$ being the unrestricted reduced form estimator, while $\pi_3$ is the restricted reduced form estimator. The symbol "Vec(·)" implies the vectorization of the matrix within the parentheses (see Judge et al., p. 949). Denote the parameter covariance matrices associated with $\mathrm{Vec}(\pi_o)$ and $\mathrm{Vec}(\pi_3)$ by $\Omega_o$ and $\Omega_3$. Then a Hausman specification test statistic is

$$m = q' \, (\mathrm{var}(q))^{-1} \, q,$$

where $\mathrm{var}(q) = \Omega_o - \Omega_3$ is the variance of q. This test statistic is distributed as chi-square with degrees of freedom equal to the number of elements in q. Note that if the system contains identities, only the reduced form parameters of the behavioral equations would be used since including identities would cause $\Omega_3$ and $\Omega_o$ to be singular.

The covariance of the restricted reduced form parameter estimates, $\Omega_o$, is obtained through a procedure outlined by Schmidt (pp. 236-239). As a basis for discussion, assume the simultaneous equation model of the form

(4.1) $$Y\Gamma + X\Delta + \nu = Z\beta + \nu = 0$$

where Y and $\nu$ are t x g matrices of endogenous variables and structural disturbances, X is a t x k matrix of predetermined variables, parameter matrices $\Delta$ and $\Gamma$ are k x g and g x g respectively. The implied, restricted reduced form generated by the system is

(4.2) $$Y = -X\Delta\Gamma^{-1} - \nu\Gamma^{-1} = X\pi_3 + \mu.$$

Note the restricted reduced form parameter estimates are functions of the structural parameters, i.e., $\pi_3 = -\Delta\Gamma^{-1}$. Thus, following the result established by Rao (p. 385), the variance/covariance matrix of the reduced form estimates can be obtained from

(4.3) $$\text{Var}(\pi_3) = \partial\pi_3/\partial\beta \cdot \psi \cdot \partial\pi_3/\partial\beta,$$

where $\psi$ is the variance/covariance matrix of the structural parameter estimates (the elements of $\beta$) derived via 3SLS procedures. Schmidt provides a practical derivation of equation (4.3) as

(4.4) $$\text{Var}(\pi_3) = D\ W\ \psi\ W'\ D',$$

where, $D=(\Gamma^{-1})'\otimes I_k$ and W is a block diagonal matrix with $W_i$, i= 1, 2,· · G, given by $W_i=\text{plim}(X'X)^{-1}X'(Y_i,X_i)$. The matrices $Y_i$ and $X_i$ are the $g_i$ and $k_i$ endogenous and predetermined regressors appearing in the ith equation. In practice, the $g_i$ columns of the estimated reduced form parameter matrix are used in the first columns of $W_i$, since $\text{plim}(X'X)X'Y_i$ converges to the vector of population parameter values associated with the endogenous variables in the ith equation. The remainder of the $W_i$th submatrix is an auxiliary regression of the predetermined variables appearing in equation i on the complete regressor matrix.

The variance of the unrestricted reduced form, $\text{Var}(\pi_o)$, is obtained from a seemingly unrelated (SUR) estimation of the unrestricted reduced form. This procedure allows the cross-equation covariances to enter the test. The variance/covariance matrix of the SUR parameter estimates can be represented as

(4.5) $$\text{Var}(\pi_o) = (P'(\Sigma^{-1} \otimes I_k)\ P)^{-1} = \Sigma \otimes (X'X)^{-1},$$

where $P = (I_g \otimes X)$ and $\Sigma$ is the error covariance matrix from the OLS estimation of the unrestricted reduced form parameters, i.e.,

$$\Sigma = [(Y-X(X'X)^{-1}X'Y)'(Y-X(X'X)^{-1}X'Y)]/T.$$

## The Structural Model

The structural model is a seven equation, simultaneous equation model of the U.S. shrimp industry based on monthly data (Thompson, Roberts, and Pawlyk). This model was briefly discussed in the preceding chapter. The data for reestimating the model were kindly provided by Dr. Kenneth J. Roberts. Counting the intercept, there are fourteen predetermined and seven endogenous variables in the model. Each equation is over-identified with the total number of over-identifying restrictions being fifty. The endogenous variables in the model are

C - Consumption (disappearances from wholesale warehouses), thousands of pounds

Pw - Wholesale price of 26-30 count frozen shrimp, New York ($/lb.)

Pe - Exvessel price of 26-30 count shrimp, Northern Gulf of Mexico ($/lb.) thousands of pounds, lagged one month

S - End of month cold storage (stocks), thousands of pounds

I - Imports, thousands of pounds

L - Landings from U.S. Gulf of Mexico ports, thousands of pounds

TR - Fishing effort, number of fishing trips by Gulf shrimpers.

The predetermined variables in the model are

Pw1 - Wholesale price, Pw, lagged one month

Pw2 - Wholesale price, Pw, lagged two months

Pe1 - Exvessel price, Pe, lagged one month

S1 - End of month cold storage holdings (stocks), lagged one month

X2 - Currency exchange rate between U.S. and Japan (yen/dollar) lagged two months

E - Unadjusted retail sales in eating places

R - Prime rate of interest on short-term, business loans

F - Diesel fuel price (dollars/gallon)

PR - Average precipitation in coastal Louisiana, inches, lagged two months

T - Average atmospheric temperature, coastal Louisiana (degrees Fahrenheit) lagged two months

Qj - Quarterly dummy variable for second, third, and fourth quarter of the year (j=2,3,4)

$\mu g$ - Error terms (g=1,2,3,4,5,6,7)

All equations are linear in the parameters and are shown in functional form as

$$C = f(Pw, E, Q2, Q3, Q4, \mu 1)$$

$$Pw = f(S1, I, C, Pe, Pe1, Q2, Q3, Q4, \mu 2)$$

$$Pe = f(L, R, Pw, Pw1, Q2, Q3, Q4, \mu 3)$$

$$S = f(S1, L, I, C, \mu 4)$$

$$I = f(Pw2, X2, Q2, Q3, Q4, \mu 5)$$

$$L = f(PR2, T2, TR, Q2, Q3, Q4, \mu 6)$$

$$TR = f(Pe, F, L, Q2, Q3, Q4, \mu 7).$$

The authors provide very little theoretical justification of the model specification and, in general, do not specifically identify the behavior being modeled by each equation. Thus it is difficult to provide much more information regarding the rationale of their model than that contained in the functional form representations given above.

In discussing their specification, the authors note that economic theory suggests that the prices of substitute and complementary products be included in their first equation. However, their preliminary tests to identify substitution effects using the producers' price index for processed meat were unsuccessful and therefore the variable was not included in the model. Also, citing the inability of previous researchers to demonstrate significant complementarity or substitution effects, the authors did not include the prices of potential substitute or complementary products.

Thompson et al. describe the second equation in their model as a price level equation, noting that the inclusion of current and lagged exvessel prices motivates this designation and assures that wholesale and exvessel prices move together. The dependence of exvessel prices on market conditions at the wholesale level is treated by including current and lagged wholesale price in the exvessel price equation. Noting that the United States and Japan are the major competitors for world supplies of shrimp, the authors include the rate of exchange between the Japanese yen and the U.S. dollar in the equation explaining imports of shrimp into the U.S.

The equation explaining landings of shrimp reflects the influence of environmental factors on the annual shrimp crop/population.

> The quantity landed is dependent on the amount of shrimp available for harvest and the extent of fishing effort exerted by the industry. Three species of shrimp (brown, white, and pink) account for 98 percent of annual Gulf landings. Brown, white, and pink shrimp are estuary dependent during the early stages of their life cycle. Growth rates during this time will be adversely affected by low salinity levels and low water temperatures. There is a well documented correlation between salinity levels in the estuaries and amounts of precipitation along the coastal areas (Center for Wetland Resources). Average precipitation in coastal

> Louisiana was used to reflect salinity levels in Louisiana wetlands. Data on precipitation were used instead of salinity levels because the latter were not consistently available on a monthly basis. Average atmospheric temperature was used instead of water temperature in the estuaries as the latter was not available in a consistent and timely fashion. Shrimp landings follow a seasonal pattern from year to year. Landings are typically low from January through April and high in May, June, and July reflecting the spring season for brown shrimp. The gradual decline in landings after July is interrupted by the fall season for white shrimp which reaches a peak in October. Quarterly dummy variables are included in equation 6 to reflect seasonality in landings. (Thompson et al., p. 13)

The authors note that to treat the production response of the industry adequately it is necessary to include the equation explaining the effort expended in harvesting shrimp. The number of shrimping trips made by industry vessels is selected as the proxy for effort. The authors explain that due to the existence of externalities in the shrimp fishery, increased effort may or may not increase the amount of shrimp landed. "Hence, equations 6 and 7 were included to describe the 'behavior' of the industry in terms of landings and effort, respectively" (Thompson et al., p. 13).

## Hausman Test Results and Discussion

The structural model was estimated by 3SLS. The results were not in total agreement with those published by Thompson et al. due to uncertainty regarding the exact form of several exogenous variables. However, since the same data were used to construct both the restricted and the unrestricted reduced forms and their associated variances, this discrepancy will not affect the test results. Following the steps outlined in the previous section, the Hausman's m statistic was calculated using the MATRIX Procedure of SAS and presented in Appendix A. The calculated m value was 272.03. Since this statistic exceeds the critical value for a chi-square variable with 98 degrees of freedom at the 99% confidence level, the null hypothesis that the model is correctly specified is rejected.

By itself, the Hausman test result is of limited value in discovering possible causes for the rejection of the null hypothesis and in possibly finding avenues for improving the specification of the econometric model. Some of the desired information can be obtained from a consideration of the two sets of parameter estimates. To facilitate the comparison of the 3SLS reduced form parameters from the restricted model with the OLS parameters estimates from the unrestricted reduced form, Table 4.1 presents both sets of parameters along with the t-values for each parameter.

A large difference between estimated parameter values coupled with an indication of parameter significance as shown by the associated t-values greater than two signals a possible source of model misspecification. An obvious example is the fuel price variable, which is designated by the letter F. In six out of seven equations, the OLS estimate is much larger in absolute value than the 3SLS estimate. The consistency of plausible signs on the fuel price variables and consistent indication of significance across six out of seven equations argues for the inclusion of the fuel price variable in more than one equation in a respecification of the model. Apparently, this variable may reflect the fact that changes in fuel prices have impacts at all market levels. Further, it appears that fuel has a substantial effect on all of the endogenous variables with the exception of the fishing trips variable.

Table 4.1 Comparing Restricted Reduced Form Parameter Estimates with Unrestricted Reduced Form Parameter Estimates

Description of Symbols

| Symbol | Description | Symbol | Description |
|---|---|---|---|
| RRF | Restricted Reduced Form | F | Fuel Price Index |
| URF | Unrestricted Reduced Form | Pe1 | Exvessel Price Lagged One Period |
| Cn | Constant | S1 | Cold Storage Lagged One Period |
| Q2 | Second Quarter Dummy Variable | Pw1 | Wholesale Price Lagged One Period |
| Q3 | Third Quarter Dummy Variable | Pw2 | Wholesale Price Lagged Two Periods |
| Q4 | Fourth Quarter Dummy Variable | EX2 | Yen/Dollar Rate Lagged Two Periods |
| E | Expenditures in Eating Places | PR2 | Precipitation Lagged Two Periods |
| R | Interest Rate | T2 | Temperature Lagged Two Periods |

APPARENT CONSUMPTION EQUATION

| | Parameters | | t-Values | |
|---|---|---|---|---|
| | RRF | URF | t-RRF | t-URF |
| Cn | 15931.17 | -21872.27 | 9.59 | -2.12 |
| Q2 | 2406.30 | -463.02 | 1.81 | -0.32 |
| Q3 | 6777.71 | -3692.81 | 4.98 | -1.62 |
| Q4 | 6666.45 | -155.14 | 5.04 | -0.08 |
| E | 1.98 | 6.08 | 6.03 | 6.69 |
| R | 21.43 | -55.69 | 0.94 | -0.21 |
| F | -3.11 | -12234.60 | -0.42 | -2.08 |
| Pe1 | -793.60 | -1757.61 | -1.15 | -0.63 |
| S1 | 0.01 | 0.01 | 1.00 | 0.31 |
| Pw1 | -56.31 | -817.36 | -0.48 | -0.34 |
| Pw2 | 277.75 | 779.60 | 1.13 | 0.46 |
| EX2 | 2.21 | 69.33 | 1.07 | 3.57 |
| PR2 | -1.00 | 54.26 | -0.54 | 0.34 |
| T2 | 1.46 | 217.61 | 0.59 | 2.99 |

EXVESSEL PRICE EQUATION

| | Parameters | | t-Values | |
|---|---|---|---|---|
| | RRF | URF | t-RRF | t-URF |
| Cn | 1.87 | 2.00 | 2.88 | 4.26 |
| Q2 | -0.16 | -0.09 | -1.32 | -1.41 |
| Q3 | -0.36 | -0.17 | -2.37 | -1.61 |
| Q4 | -0.10 | -0.00 | -0.72 | -0.04 |
| E | 0.00 | -0.00 | 2.28 | -1.95 |
| R | -0.05 | -0.04 | -2.74 | -3.08 |
| F | 0.01 | 0.79 | 0.44 | 2.94 |
| Pe1 | 1.03 | 0.79 | 3.70 | 6.27 |
| S1 | -0.00 | -0.00 | -2.37 | -3.50 |
| Pw1 | 0.12 | 0.14 | 0.57 | 1.27 |
| Pw2 | -0.36 | -0.05 | -2.50 | -0.60 |
| EX2 | -0.00 | -0.00 | -1.90 | -3.29 |
| PR2 | 0.00 | 0.01 | 0.61 | 1.77 |
| T2 | -0.00 | -0.00 | -0.67 | -0.54 |

LANDINGS EQUATION

| | Parameters | | t-Values | |
|---|---|---|---|---|
| | RRF | URF | t-RRF | t-URF |
| Cn | -20957.91 | -25404.98 | -3.47 | -2.84 |
| Q2 | 3776.62 | 4210.54 | 1.86 | 3.34 |
| Q3 | 1841.08 | -3395.27 | 0.57 | -1.73 |
| Q4 | -2206.48 | -3913.69 | -0.82 | -2.26 |
| E | 0.08 | 2.53 | 0.71 | 3.21 |
| R | -20.70 | 161.37 | -0.72 | 0.72 |
| F | -1038.65 | -11318.49 | -0.58 | -2.22 |
| Pe1 | 457.52 | -2687.60 | 0.73 | -1.12 |
| S1 | -0.00 | -0.02 | -0.76 | -0.62 |
| Pw1 | 54.40 | 335.06 | 0.45 | 0.16 |
| Pw2 | -160.13 | 843.85 | -0.72 | 0.58 |
| EX2 | -1.27 | 2.55 | -0.70 | 0.15 |
| PR2 | -333.14 | -275.48 | -1.38 | -2.00 |
| T2 | 488.24 | 521.37 | 4.64 | 8.29 |

WHOLESALE PRICE EQUATION

| | Parameters | | t-Values | |
|---|---|---|---|---|
| | RRF | URF | t-RRF | t-URF |
| Cn | 2.13 | 2.60 | 3.14 | 4.21 |
| Q2 | -0.16 | -0.10 | -1.22 | -1.17 |
| Q3 | -0.41 | -0.18 | -2.74 | -1.32 |
| Q4 | -0.14 | -0.00 | -1.00 | -0.03 |
| E | 0.00 | -0.00 | 2.48 | -1.93 |
| R | -0.03 | -0.02 | -1.76 | -1.38 |
| F | 0.00 | 0.79 | 0.44 | 2.25 |
| Pe1 | 1.17 | 0.44 | 5.83 | 2.65 |
| S1 | -0.00 | -0.00 | -2.36 | -3.55 |
| Pw1 | 0.08 | 0.51 | 0.53 | 3.48 |
| Pw2 | -0.41 | -0.02 | -2.72 | -0.19 |
| EX2 | -0.00 | -0.00 | -1.93 | -3.33 |
| PR2 | 0.00 | 0.00 | 0.59 | 0.36 |
| T2 | -0.00 | -0.00 | -0.66 | -0.35 |

Table 4.1 Continued:

COLD STORAGE EQUATION

| | Parameters | | t-Values | |
|---|---|---|---|---|
| | RRF | URF | t-RRF | t-URF |
| Cn | -27353.80 | -25497.42 | -5.08 | -2.99 |
| Q2 | 502.80 | -431.02 | 0.30 | -0.36 |
| Q3 | -2067.62 | -1120.76 | -0.78 | -0.60 |
| Q4 | -80.54 | 541.96 | -0.04 | 0.33 |
| E | -1.34 | -0.38 | -4.15 | -0.51 |
| R | -31.73 | 134.56 | -1.06 | 0.63 |
| F | -829.51 | -4942.58 | -0.58 | -1.02 |
| Pel | 927.49 | 1650.80 | 1.32 | 0.72 |
| S1 | 0.97 | 0.95 | 57.07 | 25.37 |
| Pw1 | 83.37 | 115.64 | 0.50 | 0.06 |
| Pw2 | 1425.36 | 177.00 | 3.42 | 0.13 |
| EX2 | 11.32 | 13.20 | 1.55 | 0.82 |
| FR2 | -266.06 | -215.47 | -1.38 | -1.64 |
| T2 | 389.93 | 330.87 | 4.66 | 5.52 |

IMPORTS EQUATION

| | Parameters | | t-Values | |
|---|---|---|---|---|
| | RRF | URF | t-RRF | t-URF |
| Cn | 7584.98 | -16969.66 | 2.47 | -1.92 |
| Q2 | -958.78 | -3334.98 | -0.84 | -2.67 |
| Q3 | 1462.16 | -4874.43 | 1.27 | -2.50 |
| Q4 | 7483.64 | 3546.66 | 6.64 | 2.07 |
| E | 0.00 | 3.73 | 0.00 | 4.79 |
| R | 0.00 | -233.30 | 0.00 | -1.05 |
| F | 0.00 | -8162.48 | 0.00 | -1.62 |
| Pel | 0.00 | 1382.22 | 0.00 | 0.58 |
| S1 | 0.00 | 0.00 | 0.00 | 0.04 |
| Pw1 | 0.00 | -1386.32 | 0.00 | -0.67 |
| Pw2 | 2046.29 | 924.37 | 6.58 | 0.64 |
| EX2 | 16.25 | 68.42 | 1.78 | 4.11 |
| FR2 | 0.00 | 56.41 | 0.00 | 0.41 |
| T2 | 0.00 | 86.41 | 0.00 | 1.39 |

FISHING TRIPS EQUATION

| | Parameters | | t-Values | |
|---|---|---|---|---|
| | RRF | URF | t-RRF | t-URF |
| Cn | -58747.00 | -47905.72 | -3.45 | -1.90 |
| Q2 | 13132.00 | 15391.67 | 2.09 | 4.34 |
| Q3 | -3093.84 | -11584.34 | -0.34 | -2.09 |
| Q4 | -8091.91 | -9508.49 | -1.00 | -1.95 |
| E | 0.38 | 0.06 | 0.88 | 0.03 |
| R | -103.98 | 388.96 | -0.91 | 0.61 |
| F | -5216.51 | -3481.85 | -0.67 | -0.24 |
| Pel | 2297.86 | 337.16 | 0.94 | 0.05 |
| S1 | -0.02 | -0.28 | -0.94 | -2.54 |
| Pw1 | 273.20 | 1186.82 | 0.49 | 0.20 |
| Pw2 | -804.24 | -2972.05 | -0.91 | -0.72 |
| EX2 | -6.38 | -2.73 | -0.86 | -0.06 |
| FR2 | -830.77 | -134.98 | -1.36 | -0.35 |
| T2 | 1217.56 | 1341.18 | 4.06 | 7.57 |

An associated point is that since the structural model only permits fuel price to enter the trips equation, it appears that this variable's effect is not communicated to the rest of the restricted reduced form equations. This suggests that the trips equation is not important in affecting landings and, hence, other endogenous variables.

The explanatory weakness of the trips equation may be due to problems inherent in the trips variable.

For example, the trips variable, included in the structural model as a proxy for fishing effort, may be inappropriate for this task. Shrimpers may take the same number of trips per time period, but adjust the amount of fishing time per trip on the basis of fuel and shrimp prices. Thus, the number of trips they make may not be very powerful in explaining fishing effort. These considerations argue for dropping the trips equation from a respecification of the model and adding the fuel variable in several of the other equations.

Another variable associated with significant parameter estimate differences between the restricted and unrestricted reduced forms is "expenditures in eating places," E. Since the OLS estimates of the parameter on E are often larger than those estimated by the 3SLS estimator, it may be argued that the econometric specification results in the impact of expenditures being underestimated. This may be especially important in considering the policy implications of the econometric model's estimation of the impact of expenditures on apparent consumption and on imports. The unrestricted model suggests that expenditures may have a much larger impact on landings as well as on consumption and on imports than suggested by the econometric model. On the positive side, it appears the unrestricted model supports the Thompson et al. decision to exclude expenditures from the wholesale price, exvessel price and cold storage equations.

The expenditure variable can be interpreted as a proxy variable for income as noted by Thompson et al. In this interpretation, it can be used to calculate an income elasticity of demand for shrimp. In their article, Thompson et al. calculated the elasticity of demand related to retail expenditures to be in the inelastic range (.42 percent). However, if the unrestricted model is correct in indicating that the econometric model substantially underestimates the impact of expenditures on consumption, then it is possible that the income elasticity of demand for shrimp is in the elastic range. As shown in Table 4.1, the unrestricted reduced form parameter estimate on expenditure is three times larger than the restricted reduced form estimate. This difference in value is enough to boost the estimated elasticity into the elastic range. The policy implications of one estimate versus the other are substantially different.

The results relating to the Yen/Dollar exchange rate variable also merit discussion. The unrestricted model indicates that this variable should be added to the apparent consumption equation. In agreement with the model specified by Thompson et al., the unrestricted model indicates the exchange rate variable should not be included in the wholesale price equation or the exvessel price equation. An examination of the t-values listed in Table 4.1 indicates that the two models are largely but not completely in agreement regarding the restrictions placed on the model by the analysts.

A final point is the relation between the reduced form Hausman test developed here and the structural test Hausman presents in his paper. This latter test compares $\mathrm{Vec}(\beta_3)$ and $\mathrm{Vec}(\beta_2)$ where these symbols represent the three and two stage least squares structural estimators respectively. Unfortunately, this test has little power if the off diagonal elements of the error covariance matrix are near zero. Additionally, there is no guarantee that any of the elements of $\beta_2$ are consistent if the over-identifying restrictions are incorrect. A test of this type, i.e., comparing Vec($\beta_3$) and Vec($\beta_2$), was run on the Thompson et al. model. The results indicate that the hypothesis of proper specification cannot be rejected at any conventional significance level. The inconsistency of the two tests is an obvious subject for further research.

## Summary

Although the specification test results relating to the existing SEM indicate that the null hypothesis of no misspecification could be rejected, the analysis of the two reduced form parameter values generally supported, with some notable exceptions, the original analysts' theoretical decisions regarding which variables to include in a given equation. These results may indicate that the misspecification in the existing SEM may not be very serious. Indeed, a comparison of the policy implications of the existing model with those of the respecified model to be discussed in Chapters VII and VII suggests that the policy implications of the existing model are robust to the misspecification. However, the results do indicate that several variables should be added to the model in various locations, indicating disagreement with the theorists' parameter restrictions. These results should be useful in respecifying the structural model.

# CHAPTER V
# VECTOR AUTOREGRESSIVE MODELS

The primary purpose of this study is to better understand the relationships among relevant economic variables associated with the U.S. shrimp market for policy making purposes. Typically the approach to this problem is sought within the context of a simultaneous econometric model (SEM). However, for several reasons, including the analysts' incomplete understanding of the time related relationships among the variables of interest, the resulting simultaneous models are misspecified. This study hypothesizes that the analysts' understanding of the economic phenomena under study and the analysts' later specification of a related SEM can be improved by the knowledge gained from the specification and analysis of a vector autoregressive (VAR) specification of the subject.

## Vector Autoregressive Theory

Understanding the reasoning for selecting the VAR approach begins with the standard explanation that the simultaneous econometric model can be expressed as part (the complete system may contain a trend component: see Judge et al., P. 686) of a multivariate, autoregressive moving average time series (ARMA) model (cf. Quenouille, 1957; Theil and Boot, 1962; Zellner and Palm, 1974; Wallis, 1977, or Anderson et al., 1983). A general dynamic simultaneous equation model (SEM) can be written as

(5.1a) $$A(L)Z_t + B(L)X_t = C(L)\epsilon_t$$

and

(5.1b) $$D(L)X_t = F(L)\nu_t,$$

where $Z_t$ is a vector of endogenous variables, A(L), B(L), C(L), D(L), and F(L) are matrices of polynomials in the non-negative powers of the lag operator L, $X_t$ is a vector of exogenous variables, and where, $\epsilon_t$ and $\nu_t$ are vectors of random serially uncorrelated errors assumed to have zero mean and constant variances. The system in (5.1) can be combined to form the single ARMA model

(5.2) $$G(L)\ Y_t = H(L)\mu_t,$$

where G(L) and H(L) are appropriately restricted matrices having nonzero elements A(L), B(L), D(L), and C(L) and F(L), respectively, and $Y_t$ is the vector containing both $Z_t$ and $X_t$. In general, $J(L) = J_0 + J_1L + J_2L^2 + J_3L^3 + \cdot\cdot\cdot$, where J = A, B, C, etc. If H(L) is invertible, the ARMA model in (5.2) can be expressed in the purely autoregressive form

(5.3) $$A(L)\ Y_t = \mu_t,$$

where A(L) has been redefined as $A(L)=(H(L))^{-1}\ G(L)$. Then, the autoregressive form in (5.3) can be written in a generalized, restricted, reduced form

(5.4) $$Y_t = A(L)Y_{t-1} + \mu_t,$$

where A(L) has again been appropriately redefined. The equation system in (5.4) is restricted such that the $X_t$ subvector of $Y_t$ is exogenous. If these restrictions are not imposed, the unrestricted reduced form is obtained. Both the restricted and the unrestricted form are purely autoregressive systems; and, since $Y_t$ is a vector, the systems are known as vector autoregressive systems. Thus, the VAR system is an unrestricted reduced form of some unknown structural system of equations; alternatively, the VAR model is consistent with many different structural models. These considerations argue in favor of using the VAR specification of the economic phenomena under study because the use of the VAR specification minimizes exposure to the recognized dangers of analyst induced specification errors. As Anderson et al. (p. 250) observe in relation to univariate times series estimation: "the time series analyst is not constrained by any particular theory during the identification and estimation of the model."

A second argument for the use of the VAR specification arises directly from the generalized nature of the VAR system just demonstrated. Note that in the generalized reduced form equation system all equations have identical regressors as long as no restrictions are imposed. Thus, the system in (5.4) can be consistently estimated using ordinary least squares without being concerned about the existence of simultaneous equations bias. Furthermore, estimating each equation separately using ordinary least squares produces asymptotically consistent estimates because the right-hand side variables are the same in every equation. From a practical point of view, then, VAR models are easy to estimate because efficient and consistent estimates can be produced without using system estimation procedures (Hakkio and Morris, p. 10). More important, however, are the implications of this consistency for the estimation of the desired population parameter values. If one assumes that the data in the sample have been generated by a process that could be represented by an appropriately specified

SEM, then the estimates of properly specified VAR model are consistent with the information in the data sample, and therefore, consistent with the underlying, but unspecified SEM. Thus, the VAR model provides a practical method of obtaining consistent estimates of population parameters for use in the prediction and control of economic phenomena, while minimizing exposure to specification errors made in a limited information environment.

Some preliminary evidence relating to the robustness to misspecification of VAR models versus SEM models has been presented by Hakkio and Morris (1984, p. 51). Their results indicate that point estimates from a VAR model are more robust to model misspecification than point estimates from a structural model. However, they found that point estimates from a structural model are more efficient than those from a VAR model except when the model is badly misspecified. Hakkio and Morris speculate that the VAR specification is more robust because it is a less restrictive system of equations than is the SEM.

An additional attraction of the VAR specification is that its parameter matrix, the matrix, A(L), in equation system (5.4), contains information on the relationships between the variables included in the vector $Y_t$. This information can be quite useful for prediction purposes and can also provide guidance in policy matters. Thus, the VAR specification has several characteristics which recommend its use in applied work.

## Estimation Procedures

Estimating the VAR model is simplified by its linear form and the fact that the regressors in all equations are identical. As noted above, this results in least squares parameter estimates coinciding with the maximum likelihood estimates. Once the exogenous and endogenous variables to be included in the model are selected, the specification of the model is completed by deciding where the variables enter the model. The VAR model is composed of three parts the exogenous variables, the endogenous variables, and the error vector. The exogenous variables will include the intercept, the indicator or dummy variables, the trend variable, and any other variable judged to be exogenous to the system of endogenous variables. Such a model can be represented as

$$Y_t = b_t + A(L)Y_{t-1} + \epsilon_t, \tag{5.5}$$

where $Y_t$ is a vector of the endogenous variables and $b_t$ is a vector composed of the indicator variables, the trend and intercept variables, and the selected exogenous variables.

## Determining the Order of the Model

A complication arises in selecting the order of the autoregressive portion of the model. This selection is accomplished by sequentially adding lags of the vector $Y_t$ to the model and testing whether the added variables have estimated parameters that are significantly different from zero.

Several tests of the null hypothesis that the parameters of the added variables are not significantly different from zero are available. Nickelsburg studied the small-sample properties of six criteria using Monte Carlo techniques and found none to be clearly superior to the others. Nickelsburg also noted a tendency for the criteria to underfit. Thus, the obvious procedure is to calculate the values of several criteria and base the decision on the combined information. Accordingly, four criteria were selected for calculation. The criteria are Akaike's AIC criterion, Schwartz's SC criterion, the likelihood ratio statistic (LR), and Sims' modified likelihood ratio test (SMLR). The criteria are represented by

$AIC(j) = \ln|\Sigma_j| + (2\ k^2\ j)/t,$

$SC(j) = \ln|\Sigma_j| + (k^2\ j\ \ln t)/t,$

$LR(j\text{-}m) = t(\ln|\Sigma_j| - \ln|\Sigma_m|),$

$SMLR(j\text{-}m) = t-((k*m)+s)(\ln|\Sigma_j| - \ln|\Sigma_m|),$

where $\Sigma_j$ is the error variance/covariance matrix of the test version of the model having j included lags of the dependant variable vector, k is the dimension of the Yt vector, j and m are the number of lags in the test version of the model, $j < m$, and s is the number of exogenous regressors in the system (Sims p. 17). The decision rule for the first two criteria is to select the model of order j that minimizes the value of the criterion. The last two criteria are distributed asymptotically as chi-square with degrees of freedom equal to the number of restrictions placed on the restricted model $k^2(m-j)$. Thus, the decision rule is to test, pairwise, models of increasing order and select the model with the largest lag not rejected as insignificant.

The purpose of adding lags of the dependent variable until the error process becomes white noise is to remove the influence of past values of a variable on its present value. This process is in accordance with the notion that a major portion of the variation in a time series can be explained with reference only to its past values (cf. Pierce, 1977). The necessity of random or white noise residuals is also required in Chow's technique, discussed below, of analyzing the lead/lag relationships among the variables in the endogenous system.

The variation remaining in the error process after pre-whitening will be a combination of random variation and the variation caused by other variables (cf. Greenberg and Webster, p. 153). Thus, by analyzing the residuals of pre-whitened time series the influence of other variables on a variable of interest can be detected. The technique employed here is analogous to the pre-whitening processes employed in well-known causality testing procedures; however, instead of pre-whitening each time series individually, the vector of time series variables are treated simultaneously.

## Hosking's Test for White Noise

Testing for a white noise error process in the context of a multivariate system is accomplished using Hosking's (p. 605) multivariate portmanteau statistic

$$P = n\Sigma_{r=1\ldots s}\ \mathrm{tr}(Cr'C_o^{-1}C_rC_o^{-1}),$$

where n is the number of observations, tr is the trace operator, $C_r$ and $C_o$ are the estimated autocovariance matrices of the vector of endogenous variables at the rth and zero lag levels, respectively and $s=O(n^{1/2})$. Note that $s=O(n^{1/2})$ implies that s is at most of order $n^{1/2}$ (Greenberg and Webster, p. 313). The portmanteau statistic is distributed as chi-square with $k^2(s-p)$ degrees of freedom, where k is the dimension of the endogenous vector and p is the order of the VAR process.

## Estimating Relationships Among Variables

Once the VAR model has been estimated, the information concerning the relationships among the variables in the model can be obtained by two alternative techniques. One technique involves decomposing the parameter matrix of the simultaneous system to discover the trigonometric functions implied by its characteristic roots. The other detects relationships between two variables by considering the correlations between the variables at various distances in time, i.e., at various lag levels. These two techniques are also known as analyses in the frequency dimension and in the time dimension, respectively. The two techniques will be discussed sequentially.

### Decomposition of the Parameter Matrix

The exogenous variables in section b of the model at (5.5) can be dropped since they are hypothesized to have no simultaneous relationship with the endogenous variables in the simultaneous system. The generalized model at (5.5) becomes equivalent to the model at (5.4) which can be rewritten without the lag operator as

$$Y_t = A_1Y_{t-1} + A_2Y_{t-2} + \cdots + yA_mY_{t-m} + U_t.$$

By adding an appropriate identity for m-1 of the m lags, this system can be rewritten as

$$\begin{bmatrix} Y_t \\ Y_{t-1} \\ Y_{t-2} \\ Y_{t-3} \\ \cdot \\ \cdot \\ \cdot \\ Y_{t-m+1} \end{bmatrix} = \begin{bmatrix} A_1 & A_2 & A_3 & \cdots & & Am \\ I & 0 & 0 & \cdots & & 0 \\ 0 & I & 0 & \cdots & & 0 \\ 0 & 0 & I & \cdots & & 0 \\ \cdot & & & & & \cdot \\ & \cdot & & & & \cdot \\ & & \cdot & & & \cdot \\ 0 & 0 & 0 & \cdots & I & 0 \end{bmatrix} \cdot \begin{bmatrix} Y_{t-1} \\ Y_{t-2} \\ Y_{t-3} \\ Y_{t-4} \\ \cdot \\ \cdot \\ \cdot \\ Y_{t-m} \end{bmatrix} + \begin{bmatrix} U_t \\ 0 \\ 0 \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ 0 \end{bmatrix}.$$

By redefining vector names, the system can be written as a first-order system with the more compact matrix form

(5.6) $$Y_t = AY_{t-1} + U_t.$$

Here $Y_t$, $Y_{t-1}$, and $U_t$ are km x 1 vectors, k being the number of variables in each vector and m being the number of lags; and A is the km x km matrix of parameters. Since the error vector would have been shown to be insignificantly different from a vector of zeros in the estimation and testing phase discussed above, it can now be set equal to zero and the equation system in (5.6) becomes a homogeneous, linear system of difference equations of the form, $Y_t = AY_{t-1}$. The solution to such a system is $Y_t = A^tY_0$.

Assuming for the moment that $Y_t$, A, and $Y_0$ are scalars, one can quickly appreciate how A characterizes the time path of $Y_t$. The following relations can be seen

if $|A| > 1$, the solution path is explosive

if $|A| < 1$, the solution path is damped

if $A < 0$, the solution oscillates

if $A > 0$, the solution path is monotonic.

In the case of a multivariate system, in which $Y_t$, A, and $Y_0$ regain their matrix designations, the matrix A again characterizes the time path of $Y_t$. Of course, eliciting the desired information is somewhat more complicated under these more interesting circumstances. Chow (chpt. 2) shows how this is accomplished by utilizing the characteristic roots and characteristic vectors of matrix A.

## Frequency Dimension Analysis

A characteristic root of A is a scalar, $\lambda$, that satisfies $|A-\lambda I|= 0$. With A being a square matrix of dimension p, where p=km, p roots will be obtained. Associated with each characteristic root, $\lambda_i$, is a characteristic vector, $b_i$, which satisfies $Ab_i = \lambda_i b_i$. Writing this equation in expanded form yields

$$A(b_1, \cdot \cdot \cdot, b_p) = (\lambda_1 b_1, \cdot \cdot \cdot, \lambda_p b_p)$$

$$= (b_1, \cdot \cdot \cdot, bp) \cdot \begin{bmatrix} \lambda_1 & \cdot & & 0 & 0 \\ & & \cdot & & \\ 0 & 0 & & \cdot & \lambda_p \end{bmatrix}$$

Denoting by B, the matrix $(b_1, \cdots bp)$, whose columns are the characteristic vectors of A and setting D equal to the diagonal matrix with the characteristic roots represented by $\lambda_i$ along its main diagonal, the system of characteristic roots and vectors can be written AB = BD or, equivalently, $A = BDB^{-1}$. This implies the solution, $Y_t = A^t Y_0$ can be written $Y_t = BD^t B^{-1} Y_0$.

To simplify some of the mathematical computations involved in deriving this solution, Chow, p.26, introduces the canonical variables, $Z_{it}$, with the vector form representation: $Z_t = B^{-1}Y_t$ or $Y_t = BZ_t$. Using the expressions $A = BDB^{-1}$, $Z_{t-1} = B^{-1}Y_{t-1}$, and $Y_t = AY_{t-1}$, the $Z_t$ can be redefined as $Z_t = B^{-1}Y_t = B^{-1}(BDB^{-1})Y_{t-1} = DZ_{t-1}$. The solution to $Z_t = DZ_{t-1}$ is $Z_t = D^t Z_0$. Thus, the solution for $Y_t$ can be expressed in terms of the canonical variables as $Y_t = BD^t Z_0$. The solution for individual elements of $Y_t$ is given by

$$Y_{it} = B_{i1}(Z_{10}\lambda^t{}_1) + B_{i2}(Z_{20}\lambda^t{}_2) + \cdots + B_{ip}(Z_{p0}\lambda^t{}_p). \quad (5.7)$$

This expression gives the time path for the endogenous variable $Y_{it}$. If some of the $\lambda_i$ are complex numbers, a cyclical time path is indicated. Further analysis of these complex numbers can reveal information concerning the related variable's cycle frequency and phase shift (lead or lag) relationship with other variables in the system.

A complex root, $\lambda$, is defined as $\lambda = a + bi$ where $i = (-1)^{1/2}$ and a and b are real numbers. The term, complex, arises from the fact that the complex root is composed of a real part, a, and an imaginary part, bi, i being an imaginary number. The complex number, $\lambda$, can be represented on a Cartesian plane with imaginary values mapped along the vertical axis and real numbers along the horizontal axis. The length of a ray from the origin to the point (a,b) is the absolute value of the complex number, $\lambda$, and is called the modulus of $\lambda$. Using plane trigonometry, the modulus is calculated by $|\lambda| = (a^2+b^2)^{1/2}$, $\cos\theta = a/|\lambda|$ or $a = |\lambda|\cos\theta$ and $b = |\lambda|\sin\theta$, where $\theta$ is the angle between the modulus and the horizontal axis. Using these results, the complex characteristic root can be expressed as $\lambda = a + bi = |\lambda|(\cos\theta + i\cdot\sin\theta) = |\lambda|e^{i\theta}$. The relation, $e^{i\theta} = \cos\theta + i\cdot\sin\theta$, used here is explained by Chiang (pp. 518-520).

Returning to the solution for an individual time series variable given above in equation 2, consider the contribution a pair of complex conjugate roots, say, $\lambda_1$ and $\lambda_2$, would make to the time path of $Y_{it}$. Note that $\lambda_i{}^t = |\lambda_i|^t(\cos\theta t \pm i\cdot\sin\theta t)$ by De Moivre's theorem (Chiang, p. 522). Thus,

$$\lambda_1{}^t = |\lambda_1|^t(\cos\theta t + i\cdot\sin\theta t) = R^t e^{i\theta t}$$

$$\text{and}\quad \lambda^t{}_2 = |\lambda_2|^t(\cos\theta t - i\cdot\sin\theta t) = R^t e^{-i\theta t},$$

where $R = |\lambda_1| = |\lambda_2|$. Note also that because $B_1$, $B_2$ and $Z_{10}$, $Z_{20}$ are pairs of complex conjugates such that $B_1Z_{10} = B_2Z_{20} = S$, then $B_1(Z_{10}\lambda^t{}_1) + B_2(Z_{20}\lambda^t{}_2)$ from equation 2 can be represented by

$$SR^te^{i\phi}e^{i\theta t} + SR^te^{-i\phi}e^{-i\theta t} = SR^t(e^{i\phi}e^{i\theta t} + e^{-i\phi}e^{-i\theta t})$$

$$= SR^t[\cos(\phi+\theta t) + i\sin(\phi+\theta t) + \cos(\phi+\theta t) - i\sin(\phi+\theta t)]$$

(5.8) or $$SR^te^{i\phi}e^{i\theta t} + SR^te^{-i\phi}e^{-i\theta t} = 2SR^t\cos(\phi+\theta t).$$

Thus, the contribution of a pair of complex conjugates is a cosine function of time multiplied by a factor, $2SR^t$. As with the previous discussion relating to the characterization of a solution to a univariate system, this time path will be damped or explosive depending on the value of $R = |\lambda_1| = |\lambda_2|$. Note that the complete solution of $Y_t$ is the sum of the various individual contributions as shown by equation (5.7) and may involve additional pairs of complex roots or singular, real roots.

By studying the expression, $2SR^t\cos(\phi+\theta t)$, one can understand how the relationship between various time series (variables of interest) can be determined. Note that if $2SR^t = 1$ and $\phi = 0$, equation (5.8) would be a simple cosine function of time that would repeat itself every time $\theta t$ became some multiple of $2\pi$. For example, $\cos\theta t = 1$ when $\theta t = 0, 2\pi, 4\pi, 6\pi$, etc. More generally, $\cos\theta t = j$ when $\theta t = k, 2\pi+k, 4\pi+k$, etc. Dividing both sides of this last expression by $\theta$ reveals that $\cos\theta t$ will have the same value when $t = k/\theta, 2\pi+k/\theta, 4\pi+k/\theta$ or every $t = 2\pi/\theta$ time units. Thus, the time length of the cycle is $2\pi/\theta$, where $\theta$ is measured in radians. Equivalently, one cycle is completed in $2\pi/\theta$ time units. The frequency of the function is the number of times it repeats in one time period or frequency $= \delta =$ cycles/time. In this case, $\delta_r = 1/t = 1/(2\pi/\theta) = \theta/2\pi$. The subscript, r, occurs because there will be a frequency corresponding to each pair of complex roots in the solution of $Y_t$.

If $\phi$ is nonzero, the value of $\cos(\phi+\theta t)$ will be shifted forward or backward according to the value of $\phi$. For example, assume one time series obeyed the function $\cos(\theta t)$ at frequency, $\delta_r$, and a second time series followed $\cos(\phi+\theta t)$ at the same frequency; the first series would have the value of one when $t = 0$ while the second series would have a value of one when $t = -\phi/\theta$. The second series arrives at or becomes one before the first series. Equivalently, the second series leads the first time series by $\phi/\theta$ time units. Stated differently, the first series lags the second by $\phi/\theta$ time units. Thus, $\phi/\theta$ is the phase shift in number of time units for the function, $\cos(\phi+\theta t)$, and indicates a leading relationship with $\cos\theta t$ if $\phi$ is positive or a lagged relationship if $\phi$ is negative.

If both time series have nonzero $\phi$, the lag or lead relationship between the two, at a given frequency, is given by

$$\Gamma(\delta_r)_{ij} = \text{abs}(\phi_i - \phi_j)/\theta_r.$$

Conventional usage is that if $\theta_i > \theta_j$, series i leads series j by $\Gamma(\delta_r)_{ij}$ time units at frequency, $\delta_r$. However, when $\Gamma(\delta_r)_{ij}$ is subtracted from a complete cycle, $2\pi/\theta$, the lead-lag relationship is reversed. This result reflects the cyclical nature of the underlying trigonometric functions and implies that causal hypotheses may take the form, $Y_{it}$ leads $Y_{jt}$, or the form, $Y_{jt}$ leads $Y_i$. The appropriate conclusion relating to the lead-lag relationship depends on the results of the tests of both hypotheses.

In summary, the contribution of a pair of complex roots to the time path solution of a times series variable can be obtained by calculating an expression of the form, $2SR^t\cos(\phi+\theta t)$. The expression, $2SR^t$, will define the amplitude of the function, e.g., the magnitude of the swings above and below the trend line. The function will tend to die out or converge to the trend line if $R<1$ or tend to explode or diverge from the trend line if $R>1$. The function will have a cycle length (will complete a full cycle) in $2\pi/\theta$ time units which implies a cycle frequency of $\theta/2\pi$. The phase of the cycle will be defined by $\phi$. The time distance between two series will be defined by $\Gamma(\delta_r)_{ij} = \mathrm{abs}(\phi_i-\phi_j)/\theta_r$. Finally, the lead-lag relationship between two series is established on the basis of hypothesis testing.

The estimated dynamic properties of the various series in the VAR, as determined by the parameters of equation (5.7), are functions of the parameters of the submatrices, $A_i$, from equation (5.6). Thus, the variances of the dynamic parameters are related to the variances of the parameters of the $A_i$ matrices. Rao (p. 385) has shown that if $Y = f(X)$, then the variance of Y is $\mathrm{var}(Y) = (\partial Y/\partial X)'\cdot\mathrm{cov}(X)\cdot(\partial Y/\partial X)$. In the present case, the phase angles and frequency angles are functions of the elements of the matrix A in equation 5.6; i.e., they are a function of the parameter estimates. Thus, the variances of the estimated angles and frequencies can be found using Rao's result. For example, the variance of the frequency angle, $\theta$, is

$$\mathrm{var}(\theta) = (\partial\theta/\partial A)'\cdot\mathrm{cov}(A)\cdot\partial\theta/\partial A,$$

where $\mathrm{cov}(A)$ is the variance/covariance matrix of the estimated parameters. The value, $\partial\theta/\partial A$, is estimated by numerical differentiation, i.e., by adding a small value to individual elements of A and dividing the change in $\theta$ by the change in the individual parameter estimate.

The variances of the frequency angles can be employed in testing hypotheses that the individual frequency angles are not significantly different from zero. Assuming the frequency angle values are normally distributed, z statistics, where $z = (\theta - 0)/\sigma$ and $\sigma$ = the square root of the variance of the frequency angle, can be calculated and used in the hypothesis tests. Since these tests are valid only if the sample statistics are normally distributed, a test of the normality assumption should be conducted prior to testing.

## Time Dimension Analysis

A second method of determining the relationships among variables of interest is to analyze how the variables of interest are correlated over time. This procedure is facilitated by considering the group of variables of interest as a vector. The correlations can then be calculated as autocorrelations, i.e., the correlation of a variable with sequentially higher ordered lags of itself. Using matrix algebra, the result will be a series of matrices whose elements will be the covariance relationships among the variables of interest. Here the variables of interest are the variables in the endogenous vector of the vector autoregressive model.

The autocorrelation matrices were calculated following the procedure outlined by Chow (p. 49-54). Subtracting the expectation of equation 5.6 from itself yields

$$Y^*_t = AY^*_{t-1} + U_t, \tag{5.9}$$

where $Y^*_t = Y^*_t - E(Y^*_t)$. Multiple substitutions into equation 5.9, replacing $Y^*_{t-1}$, yields

$$(5.10) \qquad Y^*_t = U_t + AU_{t-1} + A^2U_{t-2} + \ldots + A^{t-1}U_t.$$

The autocovariance matrix, $C_r$, for $r > 0$ is

$$(5.11) \quad E(Y^*_t\, Y^*_{t-r}) = (U_t + AU_{t-1} + A^2U_{t-2} + \ldots + A^{t-1}U_t) \times$$

$$(U_{t-r} + AU_{t-r-1} + A^2U_{t-r-2} + \ldots + A^{t-r-1}U_t)$$

$$E(Y^*_t\, Y^*_{t-r}) =$$

$$= (A^rU_{t-r}U_{t-r} + A^{r+1}U_{t-r-1}U_{t-r-1}'A' + \ldots + A^{t-1}U_1U_{t-r-1}'A'^{t-r-1})$$

$$(5.12) \qquad = A^r(V + AVA' + A^2VA^{2\prime} + \ldots + A^{t-r-1}VA'^{t-r-1}),$$

where $E(U_tU_s)=0$ for $t \neq s$ and $E(U_tU_s)=V_{t-s}$. Note that the current period variance/covariance matrix (when $r=0$) is the matrix inside the parentheses in equation 5.12. Denote this variance/covariance matrix with the symbol, $\Omega$. In practice this matrix is determined by setting $t \geq n$ such that $A^nVA^{n\prime}$ is negligible. For example, in the present analysis t was set to 200.

The autocovariance matrices relating to the covariances between error terms separated by various lengths of time are obtained through equation 5.12 by raising the value of r and recalculating. By doing this sequentially, and arranging the resulting matrices in increasing order, one can observe how the covariance between any two times series changes as one variable is compared to larger lags of another variable.

The covariances between two variables, also termed the cross-covariances, reveal the lead/lag relationships between the variables. For example, the value of the cross-covariance between two variables may be highest at $r=2$, suggesting that $Y_{it}$ and $Y_{jt-2}$ are most highly related, or that $Y_{jt-2}$ leads $Y_{it}$ by two time periods (Chow, p. 52).

The correlation between two variables is obtained by dividing the cross-covariance by the square root of the product of the variances of the two series. The variances of each series are found along the main diagonal of the variance/covariance matrix (where r=0).

Understanding the significance of the calculated correlations requires measures of the standard errors of the correlations. These statistics are obtained using the technique, based on Rao's result, described earlier. In this case, the variance/covariance matrix of the autocorrelations, $\Omega$, is

$$\mathrm{var}(\Omega) = (\partial\Omega/\partial A)' \cdot \mathrm{cov}(A) \cdot \partial\Omega/\partial A,$$

where cov(A) is the variance/covariance matrix of the estimated parameters. The value, $\partial\Omega/\partial A$, is estimated by numerical differentiation, i.e., by sequentially adding a small value to individual elements of A and dividing the change in $\Omega$ by the change in the individual parameter estimate.

The practical aspects of this process are somewhat complicated; however, it is possible to provide the basis for an understanding of the process with a short example. Assume a model wherein the number of estimated parameters equals 50 and the number of endogenous variables in the model equals 5. Thus, the autocorrelation matrices at each lag are symmetric with dimensions 5 by 5. Also, assume that the variances of autocorrelations out to a lag of 10 are desired. The process would be to change the value of one estimated parameter by a small (.000001) amount and recalculate the autocovariances out to a lag of ten. Dividing each of the resulting autocovariance values by the change in the parameter (.000001) provides a 55 by 5 matrix of the numerical derivatives associated with the change in a particular parameter estimate. Because there are 50 parameter estimates, there will be 50 matrices of derivatives.

Next, the 50 matrices of derivatives must be sorted so that the derivatives associated with a given order of lag are in the same matrix. Next, each of these 11 rearranged matrices with dimensions 250 by 5 are sorted into 5 smaller matrices with dimensions 50 by 5 that contain only the derivatives associated with a particular endogenous variable (recall that there are 5 endogenous variables in the model assumed here). Each of these 55 rearranged matrices are used to pre and post multiply the variance/covariance matrix of the estimated parameters to obtain the variance/covariance matrix of the autocorrelations at each order of lag. The variances of the correlations between a single endogenous variable and itself and the other four variables, at each order of lag, are located along the main diagonals of the 55 resulting matrices. Extracting each of these diagonals as a row vector and vertically concatenating the whole group result in a 55 by 5 matrix containing 11 submatrices. Each of the 11 submatrices contains the variances of the autocovariances between the five endogenous variables at orders of lag from zero to ten.

Once the variance matrix of the autocorrelations is calculated, it can be used to test the hypotheses that the estimated autocorrelations are not significantly different from zero. A complication arises in calculating test statistics such as z-values, where $z = (c-0)/\sigma$, $c$ = the specific autocorrelation value, and $\sigma$ = the square root of the variance of the autocorrelation value, since the correlation values are not normally distributed. They lie within the unit circle. Thus an appropriate transformation of the correlation values is required before an hypothesis tests based on the normal distribution can be used. Assuming the transformed autocorrelations are normally distributed implies that a z statistic can be calculated. If the z statistic is greater than two, the hypothesis on the autocorrelation value can be rejected.

This chapter has discussed the vector autoregressive model, its estimation, and the frequency and time domain analyses for estimating relations between the endogenous variables of the model. The following chapter provides empirical applications of this material.

# CHAPTER VI
# ESTIMATING THE VAR MODEL

Estimating a vector autoregressive model of the U.S. shrimp market entails the selection of variables to be included in the model, the selection of the order of the model, and testing to assure that the residuals of the model are time independent. These steps will be discussed in sequence. The chapter concludes with a section discussing the estimated parameters of the VAR model and the relationships among the endogenous variables as revealed through analyses in the frequency and time dimensions.

## Selection of Variables in the VAR Model

The selection of variables to be included in the model is motivated by an understanding of the market and the probable effects changes in important variables will have on market participants. An additional selection criterion is parsimony. Of major concern is the exvessel price of U.S. shrimp due to the open-entry nature of the shrimp fishing industry. However, wholesale price was chosen as the single price variable in the model because it relates most directly to existing data on U.S. shrimp utilization and importation. Further, exvessel prices can be derived from the wholesale price series. Imports of shrimp were included to reflect the increasing importance of this variable in the market. Domestic landings are added as the other source of shrimp supply to the U.S. market.

End-of-the-month cold storage holdings of shrimp in U.S. warehouses were included primarily to capture the effects of inventory behavior; however, they are also essential for calculating an estimate of apparent consumption. Thus, the inclusion of cold storage holdings obviates the need to include apparent consumption, since an adequate estimate of apparent consumption can be derived once landings, imports, and cold storage holdings are estimated.

Another major force in the market is thought to be the Japanese-yen/U.S.-dollar exchange rate (Thompson et al.) since foreign suppliers may choose either of these two markets depending on the relative strengths of the two currencies. An increase in the yen/$ ratio would reflect a weakening of the yen relative to the dollar and thus foreign suppliers will find sales in the U.S. relatively more attractive than sales to Japanese buyers.

Theoretical considerations suggest the inclusion of income and the prices of substitute commodities. Following Thompson et al., U.S. aggregate expenditures in commercial eating places is used as a proxy for an actual income variable such as U.S. aggregate disposable income. The use of "expenditures" is justified because approximately 80% of U.S. shrimp consumption occurs in a commercial setting. Prices of substitute products are included in the model by dividing the wholesale price of shrimp and expenditures by the gross national product implicit price deflator. The price deflator can be considered an index of all other input prices; thus, its inclusion brings in the prices of substitute inputs. In addition, its use as a deflator reduces the monetary variables to real terms, reflecting the assumption that rational economic agents only respond to changes in real prices. Completing the list of variables in the model are a trend variable and eleven (monthly) indicator or dummy variables. These variables were included to account for temporal persistence and seasonal effects.

## Selecting the Order of the VAR Model

Once the variables to be included in the model are selected, the specification of the model is completed by deciding where the variables enter the model. The VAR model is composed of three parts the exogenous variables, the endogenous variables, and the error vector. The exogenous variables will include the intercept, the indicator variables, the trend variable, and any other variables judged to be exogenous to the system of endogenous variables. In the present model, the expenditures variable was judged to be exogenous. The remaining variables (landings, imports, wholesale price, cold storage holdings, and the yen/$ ratio) enter the model as endogenous factors. The model, as shown at 5.5 of Chapter V, can be represented as

$$Y_t = b_t + AY_{t-1} + \epsilon_t, \tag{6.1}$$

where $Y_t$ is a vector of the endogenous variables and b is a vector composed of the indicator variables, the trend and intercept variables, and the expenditures variable.

Estimation of the model is accomplished using ordinary least squares techniques. The actual calculations were made on a microcomputer using the program displayed in Appendix B. The program is written in a matrix-based programming language entitled "Gauss." A complication arises in selecting the order of the autoregressive portion of the model, represented in the representation above by $AY_{t-1}$.

As described in the previous chapter, this selection is accomplished by sequentially adding lags of the vector $Y_t$ to the model and testing whether the added variables have estimated parameters that are significantly different from zero.

As noted in the previous chapter, the criteria selected for use with the order test are Akaike's AIC criterion, Schwartz's SC criterion, the likelihood ratio statistic (LR), and Sims' modified likelihood ratio test (SMLR). The decision rule for the first two criteria is to select the model of order j that minimizes the value of the criterion. The last two criteria are distributed asymptotically as chi-square with degrees of freedom equal to the number of restrictions placed on the restricted model, symbolized as $k^2(m-j)$. Thus, the decision rule is to test, pairwise, models of increasing order and select the model with the largest lag not rejected as insignificant.

Table 6.1 presents the results of calculating the values of the four criteria for the shrimp model over increasing numbers of added lagged dependent vectors. Note that the AIC, SC, and SMLR criteria indicate the model with j=1 should be selected. The degrees of freedom between two adjacent models is 25. Thus, the critical value for rejecting the null hypothesis is 37.653 at the 95 percent confidence level. The SMLR would reject all models of order higher than one until the twelfth order. The values of the maximum likelihood ratio test, given in the column headed with LR, indicate the order of the model should be at least eight; however, the other three criteria suggest a model of order one or two. The figures in the first column of Table

6.1 were calculated using the PROC MATRIX procedure of SAS to operate the program presented in Appendix C.

Table 6.1 Tests to Select the Order of the VAR Model*

| L | LDS | SC | AIC | LR | SMLR | LR1 | SMLR1 | DF | $X^2_{(.05)}$ |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.37 | 6.67 | 7.13 | | | | | | |
| 2 | 6.17 | 6.77 | 7.70 | 33.34 | 28.58 | | | | |
| 3 | 6.03 | 6.92 | 8.32 | 23.78 | 19.68 | 23.78 | 19.68 | 25 | 37.7 |
| 4 | 5.83 | 7.02 | 8.88 | 33.52 | 26.73 | 57.30 | 45.70 | 50 | 67.5 |
| 5 | 5.60 | 7.08 | 9.41 | 39.66 | 30.45 | 96.95 | 74.45 | 75 | 96.2 |
| 6 | 5.35 | 7.14 | 9.93 | 41.14 | 30.36 | 138.09 | 101.92 | 100 | 124.3 |
| 7 | 5.20 | 7.29 | 10.54 | 25.01 | 17.71 | 163.10 | 115.53 | 125 | 152.1 |
| 8 | 4.92 | 7.30 | 11.02 | 47.49 | 32.22 | 210.58 | 142.90 | 150 | 179.6 |
| 9 | 4.59 | 7.27 | 11.45 | 54.95 | 35.65 | 265.53 | 172.28 | 175 | 206.9 |
| 10 | 4.32 | 7.29 | 11.94 | 46.21 | 28.61 | 311.74 | 192.98 | 200 | 234.0 |
| 11 | 3.98 | 7.25 | 12.37 | 56.74 | 33.43 | 368.47 | 217.14 | 225 | 261.0 |
| 12 | 3.57 | 7.14 | 12.72 | 68.98 | 38.59 | 437.45 | 244.76 | 250 | 287.9 |
| 13 | 3.13 | 7.00 | 13.05 | 73.07 | 38.71 | 510.52 | 270.45 | 275 | 314.7 |
| 14 | 2.85 | 7.02 | 13.52 | 47.75 | 23.87 | 558.27 | 279.13 | 300 | 341.4 |

* The column heading symbols have the following meanings: L=Number of lags, LDS=the log of the determinant of the error covariance matrix, SC=Schwartz's SC criterion, AIC=Akaike's AIC criterion, LR=the likelihood ratio criterion, SMLR=Sim's modified likelihood ratio criterion, LR1 and SMLR1=refer to tests between a model of order 2 and sequentially higher orders, DF=degree of freedom relating to the LR1 and SMLR1 tests, $X^2_{(.05)}$ is the Chi-square value at the 95 percent level of confidence. Underlined values indicate circumstances in which the null hypothesis can be rejected.

Sims suggests that in some cases it may be advisable to investigate the significance of large lags of the endogenous vector and include those lags with significant parameters while dropping intermediate lagged variables with insignificant parameters. This possibility can be considered using the LR and SMLR criteria and the data in column LDS of Table 6.1. Columns LR1 and SMLR1 give the values of the LR and SMLR criteria when a model of order two is tested against models of sequentially higher orders. For example, the value in column LR1 on row three is the value of the LR criterion relating to a test between a model of order two and a model of order three. Similarly, the value in column LR1 on row eight relates to a test between models of order two and eight.

Underlined values indicate circumstances in which the hypothesis of zero values on the added parameters can be rejected at the .05 level, i.e., circumstances in which the test suggests that the model of choice is the higher order model. Thus, the LR criteria again argues for an higher order model; however, the implications of the other three criteria are in agreement that the model should not be specified with an order higher than one. Thus, it appears inappropriate to follow Sims's suggestion to include "high" orders of the lagged dependent vector in the present case. In fact, the weight of the evidence indicates the model should be of the first order. However, in consideration of Nickelburg's finding that "underfitting of models may be quite common" (p.183), the present model is specified as a second order VAR model.

## Testing the VAR Model

After the order of the VAR model has been selected, the model is reestimated in a restricted form that reflects theoretical judgement relating to the exogeneity of the variables in the endogenous system. In the present case this relates to the yen/$ variable. It is unlikely that any of the other variables in the system, with the exception of the trend and intercept variables, have a significant impact on the exchange rate since the shrimp market cannot be considered a major component of international trade between the U.S., Japan, and the rest of the world.

Incorporating such non-sample information as the mentioned restrictions into the estimation of the parameters of the model necessitates the use of the restricted least squares estimator. This is the estimator, denoted here by $\beta^*$, that is obtained when the sum of the squared residuals of the model are minimized subject to the restrictions. As shown in various texts, including Judge et al. (p. 472-473), the generalized least squares restricted (GLSR) estimator is the solution to the minimization problem

$$\text{minimize, over } \beta,\ (y-Z\beta)'(\Sigma^{-1}\otimes I)(y-Z\beta) \quad \text{subject to } R\beta=r,$$

where $\beta$ is the vectorization of the ordinary least squares (OLS) parameter matrix, y is the vectorization of the OLS Y matrix, Z is the block diagonal matrix with the matrices of predetermined variables associated with each endogenous variable along the main diagonal, $\Sigma$ is the OLS error covarinace matrix, and R is a matrix of zeros and ones appropriately placed to pick out the individual elements of $\beta$ subject to the restrictions in the vector r. In this case, r is a column vector of zeros. The minimization problem is solved through the technique of forming the Lagrangian and solving the partial derivatives of the Lagrangian for $\beta$. The result is

$$\beta^* = \beta + (Z'(\Sigma^{-1}\otimes I)Z)^{-1}R'[R(Z'(\Sigma^{-1}\otimes I)Z)^{-1}R']^{-1}(r-R\beta).$$

The approach used here is to first estimate $\beta$OLS and then calculate $\beta^*$ via the GLSR expression shown above. The ordinary least squares estimator is

$$\beta\text{OLS} = (X'X)^{-1}X'Y,$$

where X is the (t x 24) matrix of predetermined variables composed of an intercept, a trend, eleven binary variables (monthly dummy variables), the expenditures in eating places variable, and the first and second lag of the endogenous vector. The endogenous vector is composed of five variables: landings, imports, wholesale price, cold storage holdings, and the yen/dollar exchange ratio. The resulting estimator, $\beta$OLS, is a (24 x 5) matrix of parameter estimates.

Setting the restrictions that only the intercept and the trend variable have a significant influence on the yen/dollar ratio implies twenty exclusion restrictions on the parameters of the equation explaining the yen/dollar ratio. These parameters are found in the fifth column of the OLS estimator. Following Bewley (p. 82), these restrictions can be represented

$$R_1'(\beta \text{OLS})R_2 = G,$$

where $R_1$ is a (20 x 24) matrix composed of null and identity matrices as follows

$$R_1 = \begin{bmatrix} \begin{bmatrix} Z(8x14) & \\ & \\ Z(12x2) & I(12) \end{bmatrix} & \begin{bmatrix} I(4) & & Z(4x6) \\ Z(4x5) & I(4) & Z(4x1) \\ & Z(12x10) & \end{bmatrix} \end{bmatrix}$$

where Z(ixj) implies a null matrix with dimensions, (i x j), and I(4) is an identity matrix of dimension (4 x 4). $R_2$ is a (5 x 1) vector such that $R_2 = [0\ 0\ 0\ 0\ 1]'$ and G is a (20 x 1) null matrix. Note that since the GLSR estimator employs the vectorization of the OLS estimator, the restrictions must be transformed to operate on a column vector rather than a multi-column matrix. Bewley demonstrates this process by showing that stacking the columns of $R_1'(\beta \text{OLS})R_2 = G$ yields the restrictions employed in the GLSR estimator, i.e., $R\beta = r$, where $R = R_2' \otimes R_1$, $\beta = \text{vec}(\beta)$ and $r = \text{vec}(G)$.

Since these restrictions operate only on the parameters of the yen/dollar ratio equation they are known as "within equation" restrictions. Alternatively, in the terminology used by Bewley (p. 82), they are "uniform mixed linear constraints" (UMLC). This is convenient since Bewley (p. 102-103) shows that under the special case that restrictions placed on a model are UMLC, the generalized least square restricted estimator is equivalent to the maximum likelihood estimator, which implies that the restrictions placed on the model by the UMLC can be tested with the maximum likelihood test.

Recall that the log of the likelihood function for a multivariate, normally distributed variable is

$$L = -n/2\log(2\pi) - n/2\log|\Omega| - 1/2(y-Z\beta)'\Omega^{-1}(y-Z\beta),$$

where Z is a block diagonal matrix with matrices of predetermined variables along its main diagonal, y is the vectorization of the matrix of dependent variables, $|\Omega|$ is the determinant of the error covariance matrix, and n is the number of observations. Since the term, $(y-Z\beta)'\Omega^{-1}(y-Z\beta)$, is a scalar; the log likelihood function can be expressed as $L = c - n/2\log|\Omega|$, where c is a constant. Thus, maximizing the likelihood of an observed sample is equivalent to minimizing the determinant of the error covariance matrix of the system.

Testing the veracity of the restrictions amounts to comparing the maximum likelihood values of two systems: one with restrictions and one without. If the two values are significantly different, the parameters of the restricted variables are assumed to be significantly different from zero. The comparison has been formalized in the log likelihood ratio test, wherein the likelihood value of the restricted model is divided by the likelihood value of the unrestricted model. Symbolically, the likelihood ratio is

$$\lambda = L(\beta^{*})/L(\beta).$$

Two times the natural log of this ratio is distributed as $X^2$ with degrees of freedom equal to the number of restrictions placed on the restricted model. Thus,

$$-2\ln\lambda = -2\ln[L(\beta^{*})/L(\beta)] = -2[(c-n/2\ln|\Omega^{*}|)-(c-n/2\ln|\Omega|)] =$$
$$= n\ [\ln|\Omega^{*}| - \ln|\Omega|],$$

where the symbols remain as described immediately above.

The restrictions placed on the VAR, viz, that neither price, landings, imports, cold storage holdings, expenditures in eating places, nor the monthly dummy variables affect the yen/dollar ratio, are assumed to be correct. The calculated log likelihood ratio value of 26.06 is not large enough to reject the hypothesis that the parameter values on these variables, in the yen/dollar equation, are zero given twenty degrees of freedom.

Once the restricted form of the model has been estimated, its residual vector is tested as being essentially a random process using the Hoskings portmanteau statistic discussed in Chapter III. The portmanteau statistic is distributed as chi-square with $k^2(s-p)$ degrees of freedom, where k is the dimension of the endogenous vector, s was selected to be 20, and p is the order of the VAR process. In the present case, the statistic was calculated to be 466.36 with 450 degrees of freedom. Thus, the null hypothesis that the error process is essentially a white noise process cannot be rejected.

## Analyzing the VAR Model

Table 6.2 displays the parameter estimates of the restricted form of the vector autoregressive model. The t-values give some indication of the proper order of the VAR model. Note that in all cases, the first lag of each endogenous variable has a high associated t-value; while, this is not typically the case with the second lag of each endogenous variable. The t-values associated with the first and second lags of each endogenous variable are underlined in the table. As expected, most of the parameters on the other lagged endogenous variables are insignificantly different from zero. It is noteworthy to note that those trend parameters with high t-values have signs that might be expected. The trend in imports has been positive, while the trend in price and cold storage have been slightly negative.

Concern over the impact of imports on price focuses attention on the import variables in the price equation and on the price variables in the imports equation. Note that since the t-values on these variables are low, these relationships are not statistically significant. However, since the relationships appear to support the results of the frequency domain analysis discussed below, it is of some value to mention the following points. Both sets of parameters indicate a negative relationship between the first order lag of the predetermined variable and the dependent variable. Both sets of parameters also indicate a positive relationship between the second order lag of the predetermined variable and the dependent variable.

From a behavioral point of view these results can be seen as arising from the importer's response to prices that were current when

Table 6.2 VAR Model Restricted Parameter Estimates and t-Values

| Variables* | Equations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Landings | | Imports | | Price | | Cold Storage | | Yen/Dollar | |
| | p | t | p | t | p | t | p | t | p | t |
| Intercept | 6.5673 | 1.4417 | 4.9528 | 0.6746 | 1.0772 | 3.6947 | -11.5866 | -1.7310 | 12.0141 | 0.8123 |
| Trend | -0.0171 | -1.0121 | 0.0731 | 2.6860 | -0.0025 | -2.2810 | -0.0360 | -1.4516 | -0.0272 | -0.4962 |
| DV1 | -0.9761 | -0.8731 | 1.0467 | 0.5809 | -0.0854 | -1.1941 | 0.3979 | 0.2422 | -0.0000 | -0.0000 |
| DV2 | -2.1186 | -1.9605 | 1.4923 | 0.8568 | 0.0508 | 0.7351 | 2.7091 | 1.7061 | -0.0000 | -0.0000 |
| DV3 | 1.6094 | 1.4102 | 7.7657 | 4.2220 | 0.0471 | 0.6448 | 6.0496 | 3.6076 | -0.0000 | -0.0000 |
| DV4 | -2.5990 | -2.3795 | 5.3076 | 3.0149 | 0.2136 | 3.0552 | 5.0429 | 3.1420 | -0.0000 | -0.0000 |
| DV5 | -6.0658 | -4.6945 | 0.6641 | 0.3189 | 0.0757 | 0.9155 | -0.3339 | -0.1759 | -0.0000 | -0.0000 |
| DV6 | -7.7223 | -5.1382 | -0.7600 | -0.3138 | 0.2264 | 2.3532 | -1.2374 | -0.5603 | -0.0000 | -0.0000 |
| DV7 | -6.3040 | -3.7198 | -5.4636 | -2.0002 | 0.2226 | 2.0520 | -3.3399 | -1.3412 | -0.0000 | -0.0000 |
| DV8 | -5.5172 | -3.4104 | -0.0886 | -0.0340 | 0.1262 | 1.2190 | -0.3628 | -0.1526 | -0.0000 | -0.0000 |
| DV9 | -5.3113 | -3.3831 | -1.8198 | -0.7192 | 0.0919 | 0.9147 | -0.6732 | -0.2918 | -0.0000 | -0.0000 |
| DV10 | 6.1152 | 4.0153 | 0.0402 | 0.0164 | 0.0804 | 0.8252 | 1.0393 | 0.4644 | -0.0000 | -0.0000 |
| DV11 | 7.1512 | 6.2554 | -0.3980 | -0.2160 | 0.1382 | 1.8889 | 0.6340 | 0.3774 | -0.0000 | -0.0000 |
| Expand. | 1.4044 | 1.1916 | -2.3692 | -1.2472 | 0.0779 | 1.0324 | -2.0753 | -1.1983 | -0.0000 | -0.0000 |
| L1 | 0.5365 | 6.7763 | 0.1129 | 0.8955 | -0.0114 | -2.2600 | 0.4763 | 4.0887 | -0.0000 | -0.0000 |
| I1 | 0.0503 | 1.0778 | 0.3840 | 5.1639 | -0.0029 | -0.9722 | 0.2815 | 4.0957 | -0.0000 | -0.0000 |
| P1 | -0.8657 | -0.7230 | -0.4025 | -0.2111 | 0.7340 | 9.6306 | 1.8582 | 1.0548 | 0.0000 | 0.0000 |
| S1 | 0.0224 | 0.4164 | -0.1037 | -1.2099 | -0.0028 | -0.8085 | 0.7655 | 9.6617 | 0.0000 | 0.0000 |
| Y1 | 0.0055 | 0.2342 | 0.0083 | 0.2210 | -0.0007 | -0.4579 | 0.0105 | 0.3058 | 1.0657 | 14.6242 |
| L2 | 0.0214 | 0.2601 | -0.1633 | -1.2446 | 0.0084 | 1.6007 | -0.0189 | -0.1563 | 0.0000 | 0.0000 |
| I2 | 0.0103 | 0.2169 | 0.2601 | 3.4476 | 0.0025 | 0.8356 | 0.0829 | 1.1895 | 0.0000 | 0.0000 |
| P2 | 0.2799 | 0.2424 | 0.9834 | 0.5349 | 0.1189 | 1.6171 | 2.2257 | 1.3101 | 0.0000 | 0.0000 |
| S2 | -0.0258 | -0.4869 | 0.0640 | 0.7588 | -0.0042 | -1.2509 | 0.1684 | 2.1598 | 0.0000 | 0.0000 |
| Y2 | -0.0141 | -0.5892 | 0.0185 | 0.4792 | -0.0009 | -0.5782 | -0.0096 | -0.2719 | -0.1073 | -1.4667 |

P = parameter value. t = t-value.

* The symbols for the variables are: DV1 - DV11 = monthly dummy variables; Expand. = Expenditures in restaurants; L1, I1, P1, S1, Y1 = landings, imports, wholesale price, cold storage holdings, and the yen/dollar exchange ratio lagged one month; L2, I2, P2, S2, Y2 = landings, imports, wholesale price, cold storage holdings, and the yen/dollar exchange ratio lagged two months.

the importer decided on a particular level of import purchases. One month later, when the changed level of imports begin arriving, it has an effect on prices. In one instance, the results have captured a demand response and in the other instance, a supply response. Thus, one might conclude that within the period of one month imports have an inverse relationship with price; but, over a two month period, imports have a positive relationship with price.

One final note relating to the stability of the VAR model is of value. Since explosive time series are atypical in economic experience, it is generally believed that economic processes are stable. Thus, an acceptable model of an economic process should also exhibit stability. In the present, case, i.e., in the context of the model presented in equation 6.1; the necessary conditions for stability are that the roots or eigenvalues of the parameter matrix on the lagged endogenous variables are less than one in absolute value. As shown in the following section, the estimated VAR model meets these necessary conditions for stability.

### Frequency Domain Analysis

Following the process outlined in Chapter III, the large A matrix of equation 6.1 was decomposed to determine the frequency-determined relationships among the variables in the dependent vector of the vector autoregressive system. The actual calculations were carried out using the Gauss program detailed in Appendix B. Table 6.3 presents the results of these calculations. Three frequencies were revealed, having cycle lengths of approximately 2.3 months, three years, and five years. Reference to the associated t-values provides some indication of the degree of confidence one might place on these estimates. Accordingly, it appears that the 2.3 month cycle and the three year cycle may have some validity. On the basis of this information one might then consider the lead/lag relationships associated with each of these three frequencies.

Table 6.3 Frequency Relationships of the VAR

| | | Months | | |
|---|---|---|---|---|
| 1. | Cycle Lengths | 2.31 | 36.54 | 56.59 |
| 2. | t-Values | 7.34 | 6.13 | 0.74 |
| 3. | Phase-shift Values | | | |
| 4. | Landings | 0.15 | -17.69 | 8.86 |
| 5. | Imports | -0.52 | 6.79 | 15.83 |
| 6. | Price | 0.23 | 5.17 | -13.09 |
| 7. | Storage | 0.84 | -4.89 | -14.65 |
| 8. | Lead-Lag Relationships Associated with the 2.31 Month Cycle* | | | |
| | | Months | | |
| | | Landings | Imports | Price |
| 9. | Imports | +0.67 | | |
| 10. | | -1.64 | | |
| 11. | Price | +2.23 | +1.56 | |
| 12. | | -0.08 | -0.75 | |
| 13. | Storage | +1.62 | +0.95 | +1.70 |
| 14. | | -0.69 | -1.36 | -0.61 |
| 15. | Lead-Lag Relationships Associated with the 36.54 Month Cycle* | | | |
| | | Months | | |
| | | Landings | Imports | Price |
| 16. | Imports | +12.07 | | |
| 17. | | -24.47 | | |
| 18. | Price | +13.68 | + 1.62 | |
| 19. | | -22.86 | -34.92 | |
| 20. | Storage | +23.74 | +11.67 | +10.06 |
| 21. | | -12.80 | -24.86 | -26.48 |

*Column variables Lead (+) or Lag (-) Row Variables
*Underlining indicates the lead-lag relationship of choice.

The lead/lag relationships relating to the short-term (2.3 months) and medium-term (36.54 months) cycles are presented in Table 6.3. Note that two possibilities are given for each pair of variables: either A leads B or B leads A. For example, the figures on rows nine and ten of the table indicate that landings either lead imports by .67 months or lag imports by 1.64 months.

Since the analysis only captures a segment of continuous time, it is impossible to determine from the phase-shift value which variable is leading. This impossibility is easily understood by picturing a segment of a graph of two sine waves. If the waves are out of phase, one cannot determine, from the information contained in the graph, which of the waves is leading. The only information contained in the graph and in the frequency analysis presented here is the time distance or phase-shift distance separating the cycles of any two variables.

Recall that in the absence of additional information concerning the relationship between two variables, the designation of the leading variable among a given pair is arbitrarily set by the convention of selecting the variable with the highest positive phase-shift value as the leading variable. However, the designated lead/lag relationship between two variables can be reversed by subtracting the phase-shift time separating the two series from a complete cycle.

Given some knowledge of the process generating the data being studied, it may be that the designation of the leading variable need not be arbitrary. For example, given the time lag between ordering a shipment of shrimp from a foreign seller and the importation of the shrimp, it is unlikely that price is leading imports by less than one month, as indicated on row 12 of Table 6.3. It does appear plausible that imports are leading prices by 1.56 months as shown on row 11 of

Table 6.3. It is interesting to note that this short-term relationship between wholesale price and imports appears to be supported by the information from the three-year cycle on row 18 of Table 6.3. Note also, from data captured in the three-year cycle at rows 18 and 19, the plausibility of asserting that imports lead price in the short-term and price leads imports in the medium term. As indicated on row 19 of Table 6.3, price leads imports in the medium-term by approximately three years.

A consideration of the data on the relationship between price and storage argues for concluding that price leads storage by approximately two months. The return to storage operations is related to the price of the product. Thus, short-term storage fluctuations would not be expected to affect price, rather, that short-term price fluctuations would affect storage levels. Similar considerations indicate that landings lead wholesale price by 2.23 months in the short-term and that storage leads imports by 1.35 months. The meanings of most of the other lead-lag relationship data are somewhat more obscure. In those cases in which a reasonable argument can be made to select either of the two relational possibilities, the relationship of choice is indicated in Table 6.3 by underlining the appropriate value in rows nine through twenty-one.

## Time Domain Analysis

Following the process discussed in Chapter III, the lead-lag relationships among the variables in the endogenous vector of the VAR model were investigated through the correlations among the variables over time. This is considered an analysis in the time dimension. As demonstrated in Chapter III, the autocorrelation matrix relating to the vector of variables in the VAR model is

(6.2) $C_r = A^r(V + AVA' + A^2VA^{2\prime} + \ldots + A^{t-r-1}VA'^{t-r-1})$, where r is the lag or time distance between two variables, $V_{t-s}=E(U_tU_s)$, and A is the parameter matrix of the VAR.

The autocovariance matrices relating to the covariances between error terms separated by various lengths of time are obtained through equation 6.2 by raising the value of r and recalculating. By doing this sequentially, and arranging the resulting matrices in increasing order, one can observe how the covariance between any two times series changes as one variable is compared to larger lags of another variable.

The covariances or cross-covariances between two variables reveal the lead/lag relationships, averaged over all frequencies, between the variables (Chow, p. 52). For example, the value of the cross-covariance between two variables may be highest at r=2, suggesting that $Y_{it}$ and $Y_{jt-2}$ are most highly related, or that $Y_{jt-2}$ leads $Y_{it}$ by two time periods. Note that these time dimensional relationships are of a general nature while the relationships discovered via the frequency domain analysis are specific to the identified frequencies. Thus, the frequency denominated relationships may be expected to be more accurate than the time denominated relationships.

The correlation between two variables is obtained by dividing the cross-covariance by the square root of the product of the variances of the two series. The variances of each series are found along the main diagonal of the variance/covariance matrix (where r=0).

Appendix D presents the sequence of autocovariance matrices for the time series variables in the endogenous system of the VAR model under study here. Table 6.4 provides a summary of the information in Appendix D.

Table 6.4 Autocorrelations in the VAR Model

| | Maximum Correlation Value (r) Between Column Variable and Row Variable, Associated t-Value (t) and Lag (L) at which the Maximum Correlation Occurs | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Landings | | | Imports | | | Price | | | Storage | | | Yen/Dollar Rate | | |
| | r | t | L | r | t | L | r | t | L | r | t | L | r | t | L |
| Landings | a | | | 0.11 | 1.00 | 2 | -0.20 | -1.36 | 0 | 0.29 | 2.42 | 0 | -0.04 | -0.23 | 2 |
| Imports | -0.14 | -1.37 | 4 | a | | | b | | | -0.21 | -1.50 | 5 | 0.03 | 2.15 | 4 |
| Price | -0.27 | -1.86 | 5 | -0.30 | -2.66 | 10 | a | | | -0.56 | -3.04 | 5 | -0.41 | -1.91 | 5 |
| Storage | 0.35 | 2.91 | 1 | 0.28 | 2.03 | 5 | 0.43 | 2.48 | 9 | a | | | b | | |
| Yen/$ Rate | -0.02 | -0.12 | 0 | 0.25 | 1.51 | 0 | -0.33 | -1.71 | 0 | -0.10 | -0.64 | 0 | a | | |

a autocorrelation of a single variable
b continuously increasing cross-correlation

In general, the results of the time domain analysis provides support support for the broadly defined relationships among variables estimated via the frequency analysis; however, the two analyses are often not in agreement regarding specific details of the relationships. For example, the data in Table 6.4 indicate that imports lead price as did the frequency analysis. However, the time domain analysis indicates that imports lead price by ten months rather than the 1.55 months indicated by the frequency analysis. Similarly, both analyses indicate that landings lead wholesale price; but, the time domain analysis indicates the time-distance separating the two variables is five months rather than the 2.2 months suggested by the frequency domain analysis. Another discrepancy between the two analyses relates to the medium-term relationship between imports and storage. The frequency analysis indicates that, in the medium-term, imports lead storage by approximately twelve months. The time dimension analysis estimates the time distance between these two variables to be five months.

In some cases, the results of the two types of analysis appear to be in agreement. For example, both time and the frequency domain analysis indicate that price leads storage by approximately nine or ten months. The results of the two analyses are also reasonably close concerning the relationship between the yen/dollar ratio and imports. The frequency analysis indicates a leadership role for the yen/dollar ratio at approximately seven months. The time domain analysis indicates the time distance between the two variables to be four months; however, the cross-correlation function between the two variables is not sharply peaked at the four month lag. In fact, the difference between the cross-correlation value at the four month interval and the seven month interval amounts to only four percent of the correlation value at the four month interval (see Appendix D).

In those incidence where the results of the time domain analysis and the frequency domain differ, a knowledge of the market favors the frequency based results. For example, in the case of the relationship between imports and wholesale price, the frequency analysis result, i.e., that imports lead price by 1.55 months, appears more plausible than the alternative that imports lead price by ten months. Given that new supplies of shrimp are regularly added to storage during the spring, summer, and fall harvest seasons and during a winter importation season, it appears unlikely that imported supplies would be held in storage for ten months before moving into the wholesale market.

The alternative, that the imported supplies contribute to the available stock of shrimp ready for sale thereby affecting the wholesale price within two months, is somewhat more plausible.

Again in the case of the relationship between landings and wholesale price, the frequency-based result that landings lead price by 2.2 months appears more plausible than the time domain estimate of five months. Processing time for shrimp, from exvessel to cold storage, is less than a week or two at the most. It is assumed that once the shrimp are in cold storage, they are largely available for sale and therefore have a strong relationship with their selling price. Thus, it is difficult to understand why the correlation between wholesale price and landings would be strongest at a lag of five months. These considerations argue for heavier reliance on the frequency domain analysis rather than on the time domain analysis for policy purposes and for further modelling efforts

In summary, the VAR analysis indicates that when the U.S. shrimp market is represented by an autoregressive process of order two, a frequency domain approach provides some indication of the causative relationships among the variables. The most important of these relationships are that

1. imports affect the wholesale price of shrimp in the short run;
2. over the long run imports respond to or are affected by the wholesale price;
3. landings lead wholesale price changes in the short-term, say, within a quarter of a year;
4. the yen/dollar ratio leads imports within a year.

This information has policy implications that will be discussed in Chapter VIII and implications for specifying a simultaneous equation model of the market which is the subject of Chapter VII.

## CHAPTER VII

## RESPECIFYING THE SIMULTANEOUS EQUATION MODEL

A major objective of this study is to investigate the utility of information gained from a VAR model of the shrimp market in the specification of a SEM which could be judged as being properly specified. This chapter discusses the respecification process, presents the estimated parameters of the respecified model, presents the results of the Hausman specification test, and discusses the utility of the VAR model estimation exercise in the respecification of the respecified simultaneous equation model (SEM).

### The Respecified Model

The respecified structural model is

$C = L + I + S1 - S$

$P = f(D, C, E1, F1, P1, P2, \epsilon_P)$

$L = f(D, F2, R, R1, R2, P2, L1, L2, \epsilon_L)$

$I = f(D, Y2, F2, P2, I1, I2, \epsilon_I)$

$S = f(D, P, F1, P1, P2, S1, S2, \epsilon_S)$.

The letters in these equations have the following meanings:

D = eleven monthly dummy variables, an intercept, and a trend

C = consumption (disappearances of shrimp from cold storage)

P = the wholesale price of 26-30 count shrimp in New York

L = landings of shrimp at Gulf and South Atlantic ports

I = imports of fresh and frozen shrimp into the U.S.A.

E = expenditures in eating places

F = fuel price index

R = rainfall in southern Louisiana

Y = yen/dollar exchange ratio

S = end of period cold storage holdings

$\epsilon_i$ = error terms for the four equations (i=P, L, I, S).

Numbers indicate the variable has been lagged one or two months.

The first equation is an identity representing the physical relationship between sources of supply in a given month and disappearances from cold storage holdings during that month. The stocks of shrimp withdrawn from storage are sold to either domestic or international wholesale buyers as inputs into further processes. The majority of these processes involve transformation into retail food items in a commercial "eating place", such as a restaurant. For approximately 20 percent of the stocks, the further processing only involves that required to sell the product to the final consumer through a retail food outlet, such as a supermarket.

Because the shrimp are used as inputs in further processes, the second equation of the SEM is specified as a derived demand equation. The derived demand for an input is a function of the price or quantity of the input, the price of the product, the prices of other inputs, and selected demand shifters, such as income. In the present circumstance of inadequate cost and price data relating to the production of retail food items in commercial eating places, less than ideal data series were used as proxies for the desired data. The fuel price index was used as a proxy for the prices of other inputs. It is expected that fuel price will be negatively related to the demand for the primary input, shrimp.

If two inputs substitute for each other in a given production process, it is expected that the price of each will be positively related to the quantity demanded of the other. This reflects the theory that the profit seeking producer will attempt to equalize the the marginal output-per-dollar-of-cost of each input used. Given diminishing marginal productivity of inputs, the value of the marginal product is increased by using less of the input. Thus, individual producers will use less of the input whose price has increased and will use in its place more of those inputs whose purchase prices have remained unchanged.

Alternatively, if the inputs cannot be described as substitutes but must be combined together in fixed proportions, it is expected that the price of one will be inversely related to the quantity demanded of the other. To maintain a certain level of profit in the face of increasing costs producers must demand a higher price for their product. Given a downward sloping demand schedule for their products and assuming no change in other factors affecting the demand schedule, the higher price can only be obtained by reducing output, which implies a reduction in purchased inputs. Thus, an increase in the cost of other inputs used in producing a food item containing shrimp can be expected to cause an increase or decrease the amount of shrimp purchased according to the characterization of the production process using shrimp as an input. In the present case, it is assumed that shrimp are used in processes that could more appropriately be described as fixed-proportion processes rather than as variable-proportion processes.

Expenditures-in-eating-places was included as a proxy for final product price or, alternatively, as a proxy for income as suggested by Thompson et al. In either case, the expenditures variable is expected to be positively related to the price of shrimp. Considering the expenditures variable a proxy for price of the output, it is expected that producers will respond to an increase in price by supplying more product, which implies an increased demand for the inputs used to produce the product.

Alternatively, assuming that shrimp products are normal goods, an increase in income will result in an increase in the quantity of shrimp products demanded at every price. Given that suppliers will only supply greater quantities of shrimp if the selling price is increased, the result of a shift in demand on a fixed supply schedule will be an increase in the selling price of shrimp products. And again, the expected result will be an increase in demand for the shrimp to produce the products.

One and two month lags of the price variable were included to reflect the autoregressive nature of the market. Finally, the derived demand equation is specified in price-dependent form, reflecting the observation that the major equilibrating mechanism in food markets is price rather than quantity (c.f. Houck, p. 225 or Wohlgenant, p.739). This decision is supported by analysis of the relationship between cold storage holdings and consumption. Over the period of time from 1969 to

1986, wholesalers' maintained, on average, enough stocks for only two months of consumption.

The landings equation is assumed to represent the harvest sector's supply response. Landings of shrimp are the result of a production process and as such can be expected to respond to changes in the selling price of the product being produced, the prices of necessary inputs, and changes in environmental conditions affecting the production process. In the present case, the fuel price index is used as a proxy for the cost of production since fuel cost represents 50 to 70 percent of the variable cost of harvesting shrimp (Thompson et al., p. 14). The wholesale price of shrimp is used as a proxy for the exvessel price since additional analysis revealed a very strong relationship between the two price series and because no attempt was made to model the exvessel price in the SEM. Adams (p. 154) found a "very strong positive relation" between exvessel price and wholesale price: "A one cent change in current wholesale price was found to cause ex-vessel price to change in the same direction by .86 cents" (Adams, p. 154).

Rainfall in southern Louisiana was included as an environmentally related supply shifter. It was expected that the rainfall variable would be negatively related to landings because rainfall is associated with weather conditions that can hamper harvesting operations. For example, intense rainfall is usually associated with hurricanes which can occur during the harvesting season and severely hamper these operations. Additionally, high rainfall can adversely affect the growth rate and survival of larval and juvenile shrimp in their estuarine nursery areas. Thus, a reduced stock of harvestable shrimp can be expected to be associated with high levels of rainfall during the nursery stage of the annual crop of shrimp. Accordingly, it is expected that lagged shrimp landings will be a powerful predictor of current landings.

The imports equation is in reduced form due to the industry practice of forward contracting for imported shrimp. Importing is an intermediate level business producing a product to be used in further processing. As such, imports are a function of the costs of production and the selling price of the intermediate product. The fuel price index, lagged two months, to reflect Hu's observation that forward contracts in the industry are usually placed two to three months in advance, was selected as the proxy for costs of production. Lagged wholesale price is the selling price variable. The yen/U.S. dollar exchange ratio was included as a supply shifter, which could be viewed as an indication of the price of the raw product. As the yen/dollar ratio increases, foreign exporters have more incentive to sell their shrimp in the U.S. This puts downward pressure on the price of shrimp being imported into the U.S. and results in increased imports as U.S. importers respond to the lower cost of a prime input. Accordingly, the yen/dollar ratio variable is expected to have a positive relationship with current imports. Once again established business practices, captured in the form of lagged import values can be expected to have a major, positive relationship with current imports.

The supply of shrimp in cold storage is related to the endogenously determined wholesale price of shrimp, the cost of holding shrimp, and lags of the wholesale price and cold storage supply. If the wholesale price increases in the current period, the expected immediate response of suppliers is to sell shrimp by drawing down storage levels. The expectations of stored shrimp suppliers may have an additional effect on their decisions. If the price of their product has been increasing in the past, they may expect it to continue to increase in the future and, therefore, attempt to increase their supplies of stored shrimp.

These supply responses can be explained using the theory outlined by Brennan, who treated the demand for storage, normalized on price, as the difference between expected and current price: $P_s = E(P_{t+1}) - P_t$, where $P_s$ is the demand for storage, $E(P_{t+1})$ is the expected price of the stored product in the next time period, and $P_t$ is the price of the product in the current period. It is evident from this specification that if the expected price increases so will the demand for storage and visa versa for an increase in the current price. The supply of storage is seen as the industry's marginal cost of supply function: an increasing function of quantity stored. Thus, a change or shift in the demand for storage should bring about a change, in the same direction, in the quantity of storage. The net effect on amount stored will depend on the strength of the changes in expected price and current price.

These considerations argue for an expected negative relationship between price and storage in the current period and a positive relationship between lagged price and current storage. Finally, two lags of the storage variable are included as indicated by the order of the VAR model.

## Discussion of Analytical Results

The respecified model was estimated with the three stage least squares program used in the reestimation of the Thompson et al. model. The respecified model was subjected to the Hausman specification test described in Chapter IV. The calculated m statistic has a value of 81.0131 with 140 degrees of freedom. Thus, the null hypothesis of no misspecified cannot be rejected.

### SEM Parameter Estimates

The 3SLS parameter estimates, presented in Table 7.1, generally have the expected relationship with the associated dependent variables. In general, the parameter estimates of important variables of interest appear to be significantly different from zero as indicated by the associated t-values. One significant exception is the expenditures variable which is important for determining an estimate of the income elasticity of shrimp. Adams (p. 134, 165 and 170) found a similar result using real disposable income to explain monthly or quarterly retail shrimp prices. The autoregressive nature of the market is obvious in the parameter values and associated t-values of the lagged, dependent variables.

Several of the parameter values are of particular interest. For example, the parameter on consumption in the price-dependent, derived demand equation implies a price flexibility of -.29 for consumption within the very short-term of one month. Inverting the price flexibility figure provides an estimate of the price elasticity of demand for shrimp at the wholesale level. The resulting price elasticity estimate is in the elastic range and equals -3.45. This elasticity is reflected in the relationship between price and cold storage holdings. The parameter on current price in the storage equation implies a price elasticity of storage in the elastic range and estimated to be equal to -1.15.

Table 7.1 3SLS Parameter Estimates and Associated t-Values from the Reestimated SEM

| Variables | Equations | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Price | | Landings | | Imports | | Storage | |
| | $p^a$ | t | p | t | p | t | p | t |
| Intercept | 0.72 | 1.46 | 10.84 | 5.50 | -4.90 | -1.37 | 13.84 | 2.73 |
| Trend | 0.00 | 1.22 | 0.02 | 2.89 | 0.11 | 5.61 | -0.01 | -0.82 |
| DV1 | -0.02 | -0.25 | -0.74 | -0.70 | -0.56 | -0.43 | -1.11 | -0.66 |
| DV2 | 0.01 | 0.12 | -2.12 | -2.08 | 0.65 | 0.50 | 3.95 | 2.12 |
| DV3 | 0.13 | 1.90 | 1.29 | 1.20 | 6.53 | 5.04 | 6.00 | 3.13 |
| DV4 | 0.12 | 1.74 | -3.08 | -3.45 | 5.37 | 3.96 | 10.41 | 4.57 |
| DV5 | -0.02 | -0.18 | -6.66 | -6.09 | 0.21 | 0.15 | 1.31 | 0.62 |
| DV6 | 0.06 | 0.60 | -9.03 | -7.25 | -0.66 | -0.47 | 3.83 | 1.40 |
| DV7 | 0.00 | 0.01 | -8.35 | -5.89 | -4.61 | -3.47 | -1.45 | -0.54 |
| DV8 | -0.01 | -0.05 | -7.70 | -5.28 | 0.22 | 0.16 | -2.92 | -1.23 |
| DV9 | -0.07 | -0.58 | -7.29 | -4.95 | -1.60 | -1.22 | -4.33 | -2.06 |
| DV10 | 0.20 | 2.85 | 4.53 | 3.13 | 0.15 | 0.11 | -2.27 | -1.06 |
| DV11 | 0.19 | 2.43 | 6.32 | 5.91 | 0.99 | 0.76 | 0.80 | 0.43 |
| Y2 | b | | b | | 0.04 | 3.60 | b | |
| E1 | 0.05 | 0.47 | b | | b | | b | |
| F1 | -0.03 | -1.82 | b | | b | | -0.36 | -1.63 |
| F2 | b | | -0.19 | -1.75 | -0.68 | -3.52 | b | |
| R | b | | -0.05 | -0.80 | b | | b | |
| R1 | b | | -0.17 | -2.59 | b | | b | |
| R2 | b | | -0.18 | -2.71 | b | | b | |
| P1 | 0.81 | 8.16 | b | | b | | 24.51 | 4.39 |
| L1 | b | | 0.49 | 6.52 | b | | b | |
| I1 | b | | b | | 0.33 | 4.49 | b | |
| S1 | b | | b | | b | | 0.84 | 8.72 |
| P2 | 0.04 | 0.47 | -0.09 | -0.24 | 0.44 | 0.74 | 4.34 | 1.82 |
| L2 | b | | 0.02 | 0.24 | b | | b | |
| I2 | b | | b | | 0.17 | 2.44 | b | |
| S2 | b | | b | | b | | -0.03 | -0.33 |
| C | -0.02 | -2.31 | b | | b | | b | |
| P | b | | b | | b | | -28.97 | -4.51 |

a p = parameter value. t = t-value.
b These parameter values have been restricted to zero

Note that in calculating flexibilities or elasticities, the usual practice of calculating these values at the mean of the transformed data (as used in the model) is followed. These mean values as well as the data in its untransformed state are displayed in Appendix F.

In the long run, the dynamic response of an endogenous variable is affected by the parameters on lagged values of the variable. Specifically, the response in a second order equation is

$$C = \beta_0(1-\beta_1-\beta_2)^{-1}, \text{ where } \beta_i,\ i = 0,\ 1,\ 2,$$

is the structural parameter associated with an exogenous variable, and the first and second lags of the endogenous variable, respectively. Thus, the long run price flexibility can be obtained by adjusting the short run flexibility by the factor $(1-\beta_1-\beta_2)^{-1}$. In the case of the price dependent demand equation studied here, this adjustment factor is $6.6667 = (1-.81-.40)^{-1}$. Making this adjustment and inverting the result yields an estimate of the long run elasticity of demand in the inelastic range. The calculated value is -.52. These results imply that the wholesale level demand for shrimp is elastic in the short run and inelastic in the long run.

The flexibility of wholesale price with respect to imports is of considerable interest. Note the effect of imports on wholesale price comes through the impact of consumption, since imports are a component of consumption. The partial effect of an increase in imports, i.e., holding all other variables constant, is an equal increase in consumption. Mathematically, $\partial P/\partial I = \partial P/\partial C(\partial C/\partial I) = \partial P/\partial C$, since $\partial C/\partial I=1$. Thus, the impact or short run flexibility of wholesale price with respect to imports can be calculated using the parameter on the consumption variable. The calculated value is -.20. Thompson et al. found the wholesale price flexibility to be -.37. To obtain the long run price flexibility of imports, the short run value is adjusted by the adjustment factor, $(1-.81-.04)^{-1}$, yielding a long run flexibility of approximately -1.3. Inverting these two values implies the wholesale demand for imported shrimp is elastic in the short and inelastic in the long run.

The wholesale price flexibility for landings can be estimated in a manner that parallels that just discussed for imports. The short run or impact flexibility is estimated to be -.11. The Thompson et al. estimate for this flexibility was -.004. The long run flexibility implied by the short run value of -.11 is -.73. Thus, it appears that the wholesale demand for landings is elastic in both the short and long run.

The flexibility of price with respect to the yen/dollar ratio can be calculated from the effect of the yen/dollar ratio on imports multiplied by the effect of consumption on price since the partial impact of imports on consumption is unity. If the yen/dollar ratio increases by one unit, imports will increase by .04 units. If imports increase by .04 units, the wholesale price of shrimp will decline by .0008 units. Thus, the flexibility of price with respect to the yen/dollar ratio can be estimated to be -.08.

The responses of imports to the yen/dollar ratio and the wholesale price are also of special interest. The response of imports to changes in the lagged yen/dollar ratio is inelastic with an estimated value of .42. Converting this short run elasticity into a long term elasticity estimate requires adjusting the short run estimate by $2=(1-.33-.17)^{-1}$. Thus, the long run elasticity of imports with respect to the yen/dollar ratio is .84. The elasticity of imports to changes in the price variable lagged two months might be estimated to be inelastic with a value of .04; however, the low t-value on this parameter casts some doubt on the credibility of this elasticity estimate. However, these two elasticity estimates imply that imports have been relatively unresponsive to short-term changes in the wholesale price of shrimp in the U.S. or short-term changes in the yen/dollar exchange rate. This implication raises the question whether it may be permissible to treat imports as exogenous in a short-term model of the market.

The long run multipliers implied by the 3SLS parameter estimates were estimated and are presented in Table 7.2 along with their associated t-values. The calculation of the multipliers can be explained through reference to the following model

$$Y\Gamma = -X\Delta_0 - Y_1\Delta_1 - Y_2\Delta_2 - e,$$

where $\Gamma$ is the structural parameter matrix on the endogenous variables, X is the matrix of exogenous variables, $Y_1$ and $Y_2$ are the matrices of endogenous variables lagged one and two periods, and $\Delta_i$ for i=0,1,2, are the structural parameter matrices on the explanatory variables. By post multiplying the structural model by $\Gamma^{-1}$, the reduced form parameter matrices, $\pi_i$ for i=0,1,2, are obtained. The reduced form model can be expressed

$$Y = X\pi_0 + Y_1\pi_1 + Y2\pi_2.$$

Substituting in for $Y_1$ and $Y_2$ yields

$$Y = X\pi_0 + \pi_1(X_1\pi_0 + Y_2\pi_1 + Y3\pi_2) + \pi_2(X_2\pi_0 + Y_3\pi_1 + Y4\pi_2).$$

Continual substitution in for the lagged endogenous matrices produces an infinite series of the form

$$Y = X\pi_0 + X_1\pi_0\pi_1 + X_1\pi_0\pi_2 + X_2\pi_0\pi_1^2 + X_2\pi_0\pi_2^2 + \cdot\cdot\cdot$$

This form of the model is known as the final form. The lagged endogenous variables have been dropped from the final form by the assumption that $\pi_1^s$ and $\pi_2^s$ approach zero as s approaches zero. Taking the derivative of the final form with respect to the matrix of exogenous variables produces the long run or equilibrium multiplier matrix

$$C = \pi_0 + \Sigma\pi_0\pi_1^s + \Sigma\pi_0\pi_2^s = \pi_0(I + \Sigma\pi_1^s + \Sigma\pi_2^s),$$

where the summation is from $s=1$ to $s=\infty$. Assuming that $\pi_1^s$ and $\pi_2^s$ approach zero as s approaches infinity, this geometric series can be expressed

$$C = \pi_0(I-\pi_1-\pi_2)^{-1}$$

which is the equation used to calculate the long run multipliers given in Table 7.2.

The variances of these long run multipliers were based on the variances of the structural parameter estimates using Rao's result. This result and the derivation of a similar set of variances is discussed in Chapter IV.

Considering the information in Table 7.2, most of the parameter estimates appear to be insignificantly different from zero as indicated by t-Values less than two. However, some useful results can be obtained. The flexibility of price with respect to the yen/dollar exchange rate is estimated to be approximately, unitary elastic with a value of 1.03. The elasticity of imports with respect to the yen/dollar exchange rate is less than elastic with a value of .84. The low t-value associated with expenditures lagged one month indicates the parameter on this variable may not be significantly different from zero. However, if the value were used to estimate the flexibility of price with respect to lagged expenditures, the flexibility estimate would be .45.

Table 7.2 Long Run Multipliers of the Complete Respecified SEM

| Variables | Equations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Consumption | | Price | | Landings | | Imports | | Storage | |
| | p* | t | p | t | p | t | p | t | p | t |
| Intercept | 19.34 | 2.09 | 5.63 | 2.38 | 20.98 | 5.97 | -4.83 | -0.68 | 107.23 | 3.40 |
| Trend | 0.14 | 4.38 | 0.00 | 0.42 | 0.04 | 2.86 | 0.22 | 7.86 | -0.10 | -0.85 |
| DV1 | -1.37 | -0.68 | -0.09 | -0.17 | -1.49 | -0.67 | -1.19 | -0.46 | -8.92 | -0.65 |
| DV2 | -0.12 | -0.04 | 0.72 | 1.23 | -4.43 | -1.96 | 1.92 | 0.68 | 31.52 | 1.97 |
| DV3 | 8.62 | 2.31 | 0.64 | 1.13 | 2.51 | 1.07 | 13.57 | 3.88 | 48.28 | 2.81 |
| DV4 | 5.59 | 0.93 | 1.80 | 2.47 | -6.55 | -2.81 | 12.27 | 3.17 | 83.07 | 3.06 |
| DV5 | -4.30 | -1.85 | 0.85 | 1.38 | -13.65 | -4.98 | 1.17 | 0.39 | 9.81 | 0.61 |
| DV6 | -4.60 | -1.38 | 2.06 | 2.69 | -18.66 | -5.79 | 0.49 | 0.13 | 29.19 | 1.46 |
| DV7 | -8.79 | -3.48 | 1.41 | 2.03 | -17.16 | -6.27 | -7.94 | -2.20 | -13.23 | -0.66 |
| DV8 | -5.58 | -2.01 | 0.51 | 0.76 | -15.69 | -7.33 | 0.89 | 0.31 | -24.31 | -1.18 |
| DV9 | -7.90 | -2.58 | 0.10 | 0.18 | -14.79 | -7.47 | -3.09 | -1.18 | -35.41 | -1.66 |
| DV10 | 6.29 | 2.64 | 0.45 | 0.78 | 9.10 | 2.23 | 0.69 | 0.25 | -18.98 | -1.08 |
| DV11 | 8.37 | 4.16 | 0.43 | 0.79 | 12.72 | 3.47 | 2.35 | 0.86 | 6.11 | 0.43 |
| Y2 | 0.03 | 2.57 | -0.01 | -1.80 | 0.00 | 0.23 | 0.08 | 3.96 | 0.01 | 0.12 |
| E1 | 0.90 | 0.51 | 0.32 | 0.53 | -0.06 | -0.22 | 0.28 | 0.44 | -0.33 | -0.12 |
| F1 | -0.56 | -1.13 | -0.22 | -1.16 | 0.04 | 0.23 | -0.20 | -0.62 | -2.67 | -0.93 |
| F2 | -0.57 | -1.17 | 0.11 | 0.62 | -0.40 | -1.79 | -1.25 | -3.43 | -0.11 | -0.12 |
| R | -0.03 | -0.67 | 0.01 | 0.51 | -0.11 | -0.80 | 0.01 | 0.42 | -0.01 | -0.12 |
| R1 | -0.11 | -2.46 | 0.02 | 2.13 | -0.34 | -2.54 | 0.02 | 0.69 | -0.02 | -0.12 |
| R2 | -0.12 | -2.52 | 0.02 | 2.10 | -0.36 | -2.71 | 0.02 | 0.70 | -0.02 | -0.12 |

* p = parameter value. t = t-value.

## Prediction Experiments

A more widely used technique of gathering evidence on the utility of a given model is to compare its predictions with actual data from the time period just beyond the time period used in estimating the model. Predicting experiments of this type were conducted with both the VAR specification discussed in Chapter IV and the SEM specification discussed here. The technique involves multiplying the estimated (reduced form) parameter values from the model under study by data on the exogenous variables to obtain predictions on the endogenous variables. Mathematically, $Y_f = X_f\pi$, where f indicates the forecast values and $\pi$ is the reduced form parameter matrix. These predicted values are then compared to the observed data.

The predictions can be calculated for various lengths of time, with the prediction of the first future value being called a one-step prediction and longer predictions called the two-step, three-step, etc. The predictions can also be categorized by the extent past predictions are used to develop a given prediction. If the model contains lagged values of the endogenous variables in the predetermined variable matrix, then $Y_{f+i}$ is based on $Y_f$. If each prediction is based on the predictions of all previous periods, it can be called an extended prediction. Prediction can also be based on an "update" of the reduced form parameter matrix: $Y_{f+1} = X_{f+1}\pi_{i-1}$.

Updating the model generally implies that any new data, that has become available since the last estimation, is added to the data set and the model parameters are reestimated on the basis of all data available at the time of reestimation. This updating procedure was followed in the case of the VAR specification but not in the case of the SEM. Due to the expense of reestimating the SEM, the SEM parameter matrix was not updated. "Updating" the SEM involved adding all available observations on the endogenous variables to the predetermined data set which was then multiplied by the existing matrix of parameter estimates.

The full results of the predicting experiments with the VAR model and the SEM are displayed in Appendix E. Table 7.3 presents a condensed version of the results in a form that facilitates a comparison of the capability of the two models to predict the value of the price variable. Note that the SEM typically performs better than the VAR model. "Performance" here implies a small degree of difference between the actual and predicted values.

Table 7.3 Prediction Experiment Results

| | Percent Difference Between Actual and Predicted Value of Price | | | | | |
|---|---|---|---|---|---|---|
| | Extended Prediction | | Continuous Updating | | Updating Every Three Periods | |
| Months | VAR | SEM | VAR | SEM | VAR | SEM |
| 1 | - 4.9 | - 1.6 | - 4.9 | - 1.6 | | |
| 2 | - 6.6 | - 5.2 | - 3.2 | - 1.9 | | |
| 3 | -12.2 | -10.8 | - 6.4 | - 4.1 | -12.2 | - 1.8 |
| 4 | -20.7 | -16.6 | - 9.0 | - 6.5 | -19.7 | - 8.8 |
| 5 | -18.1 | -17.0 | - 0.9 | - 0.8 | -13.8 | - 7.6 |
| 6 | -15.6 | -11.9 | - 0.7 | + 1.0 | - 5.9 | - 4.7 |

## Exogeneity of Imports

To investigate the exogeneity of imports and to obtain an estimate of their long run impact on wholesale price, the respecified SEM was reestimated as a four equation SEM with imports being represented as an exogenous variable. The four equation SEM (SEM4) was tested for misspecification using the Hausman test of Chapter II. The null hypothesis of no misspecification could not be rejected with an m statistic value of 40.5576 with 100 degrees of freedom, implying that a monthly model of the market can be considered properly specified with imports as an exogenous variable. The 3SLS parameter estimates for the four equation model are presented in Table 7.4. Note that the results have the same implications for price elasticity of demand and storage as indicated by the full five-equation model.

Table 7.4 3SLS Parameter Estimates from the Four Equation SEM

| Variables | Equations | | | | | |
|---|---|---|---|---|---|---|
| | Price | | Landings | | Storage | |
| | p[a] | t | p | t | p | t |
| Intercept | 0.46 | 1.72 | 11.04 | 5.57 | 14.15 | 2.43 |
| Trend | 0.00 | 1.40 | 0.02 | 2.93 | -0.01 | -0.48 |
| DV1 | 0.00 | -0.08 | -0.79 | -0.74 | -1.01 | -0.53 |
| DV2 | 0.05 | 0.82 | -2.19 | -2.13 | 4.92 | 2.27 |
| DV3 | 0.11 | 1.78 | 1.20 | 1.11 | 6.77 | 3.05 |
| DV4 | 0.13 | 2.12 | -3.14 | -3.52 | 11.74 | 4.40 |
| DV5 | 0.00 | -0.04 | -6.75 | -6.15 | 1.51 | 0.63 |
| DV6 | 0.12 | 1.65 | -9.16 | -7.31 | 5.59 | 1.71 |
| DV7 | 0.06 | 0.73 | -8.50 | -5.97 | -0.04 | -0.01 |
| DV8 | 0.04 | 0.44 | -7.85 | -5.35 | -1.92 | -0.70 |
| DV9 | 0.00 | 0.05 | -7.43 | -5.02 | -3.40 | -1.40 |
| DV10 | 0.18 | 2.87 | 4.40 | 3.03 | -0.86 | -0.34 |
| DV11 | 0.15 | 2.34 | 6.29 | 5.87 | 1.64 | 0.77 |
| E1 | 0.02 | 0.19 | b | | b | |
| F1 | -0.02 | -1.91 | b | | -0.41 | -1.66 |
| F2 | b | | -0.19 | -1.79 | b | |
| R | b | | -0.06 | -0.91 | b | |
| R1 | b | | -0.17 | -2.65 | b | |
| R2 | b | | -0.18 | -2.66 | b | |
| P1 | 0.87 | 10.44 | b | | 32.98 | 4.83 |
| L1 | b | | 0.48 | 6.34 | b | |
| S1 | b | | b | | 0.84 | 8.52 |
| P2 | 0.03 | 0.33 | -0.08 | -0.23 | 4.34 | 1.60 |
| L2 | b | | 0.02 | 0.30 | b | |
| S2 | b | | b | | -0.02 | -0.25 |
| C | -0.01 | -2.92 | b | | b | |
| P | b | | b | | -37.99 | -4.77 |

a p = parameter value. t = t-value.
b These parameter values has been restricted to zero.

The long run multipliers of the SEM4 are presented in Table 7.5. The data in Table 7.5 indicate that in the long run a one percent increase in imports will result in 0.89 percent decrease in the wholesale price of shrimp. These results imply that the price of

Table 7.5 Long Run Multipliers of the Four Equation SEM

| Variables | Equations | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Consumption | | Price | | Landings | | Storage | |
| | p | t | p | t | p | t | p | t |
| Intercept | 20.14 | 2.45 | 4.35 | 1.72 | 21.42 | 7.54 | 85.02 | 3.55 |
| Trend | 0.06 | 1.79 | 0.02 | 1.05 | 0.04 | 2.09 | -0.15 | -0.76 |
| DV1 | -0.82 | -0.46 | -0.06 | -0.10 | -1.58 | -0.71 | -7.29 | -0.57 |
| DV2 | 0.01 | 0.00 | 1.13 | 1.43 | -4.58 | -1.96 | 31.48 | 1.80 |
| DV3 | 4.07 | 1.07 | 1.49 | 1.76 | 2.16 | 0.84 | 43.60 | 2.05 |
| DV4 | 1.76 | 0.29 | 2.56 | 2.32 | -6.73 | -2.51 | 75.80 | 2.32 |
| DV5 | -5.06 | -2.44 | 0.75 | 1.03 | -13.68 | -5.03 | 7.61 | 0.52 |
| DV6 | -3.80 | -1.06 | 2.42 | 2.36 | -18.78 | -5.64 | 30.06 | 1.47 |
| DV7 | -5.10 | -2.13 | 1.36 | 1.58 | -17.29 | -6.38 | -7.12 | -0.38 |
| DV8 | -5.34 | -2.07 | 0.90 | 1.10 | -15.91 | -7.24 | -19.00 | -1.00 |
| DV9 | -5.97 | -2.24 | 0.41 | 0.57 | -14.98 | -7.54 | -27.74 | -1.41 |
| DV10 | 7.23 | 3.34 | 1.09 | 1.45 | 8.64 | 2.09 | -11.92 | -0.77 |
| DV11 | 8.24 | 4.25 | 0.86 | 1.22 | 12.48 | 3.37 | 8.06 | 0.59 |
| I | 0.76 | 8.00 | -0.09 | -2.26 | 0.02 | 0.23 | 0.47 | 0.65 |
| E1 | 0.35 | 0.19 | 0.14 | 0.19 | -0.02 | -0.15 | -0.70 | -0.19 |
| F1 | -0.46 | -1.26 | -0.21 | -1.38 | 0.03 | 0.23 | -2.09 | -0.80 |
| F2 | -0.15 | -1.09 | 0.02 | 0.40 | -0.39 | -1.80 | -0.09 | -0.39 |
| R | -0.05 | -0.90 | 0.01 | 0.80 | -0.12 | -0.90 | -0.03 | -0.54 |
| R1 | -0.13 | -2.55 | 0.02 | 1.87 | -0.35 | -2.59 | -0.08 | -0.63 |
| R2 | -0.13 | -2.58 | 0.02 | 1.96 | -0.36 | -2.67 | -0.08 | -0.63 |

* p = parameter value. t = t-value.

shrimp has been closely related to the level of imports over the period represented by the data. This is consistent with a (long-run) inelastic demand relationship between the price of shrimp and the quantity demanded as indicated by the analysis of the 3SLS estimated parameters of the complete, respecified model discussed in this chapter.

## Utility of the VAR Model

Although the VAR specification exercise was not as beneficial for the respecification process as had been expected, the information gained in the process was influential in respecifying the SEM. For example, the value selected for the order of the VAR model provided guidance on the number of lags of variables entered into the SEM. However, this second-order lag recommendation is identical with that selected by the authors of the original SEM. Presumably this recommendation could have been developed through tests performed on the SEM, without reference to the VAR results, in a manner similar to that used by the original authors. However, Thompson et al. restricted their use of lagged variables to a greater extent than would be indicated by the VAR specification. The respecification contains two lags of most variables. The exceptions to this practice occur with purely exogenous variables having insignificant parameter values. These variables were dropped from the model in accordance with the objective of parsimony when their insignificance became obvious.

The major constraint to the utilization of much of the information developed in the estimation of the VAR model in the respecification of the SEM relates to the difficulty of specifying a theoretically sound explanation for the relationships suggested by the VAR specification. For example, the frequency domain analysis of the VAR model suggested that imports lead price by approximately one and a half months. This relationship cannot be modelled directly in the SEM because imports are hypothesized to be a function of price rather than visa versa. The effect of imports on price comes through the consumption identity in the SEM. Thus, while the relationship between the two variables may exist as estimated via the VAR analysis, the relationship cannot be modelled explicitly under the constraints of existing theory.

A similar situation exists regarding the relationship between landings and storage. While it is obvious from a practical point of view that landed shrimp quickly pass into storage, thereby, explaining the VAR relationship; theory dictates that shrimp enter storage in response to a desire to produce profits, which are related to the selling price of stored shrimp rather than the amount of shrimp produced. Thus, the relationship between landings and storage identified by the VAR model is not explicitly modeled in the SEM; rather, the relationship develops through the simultaneity of the SEM.

While these examples demonstrate the atheoretical nature of the VAR model, they also illustrate the simplicity of the theoretically-based SEM. It is probable that the decision to place shrimp into cold storage is based on a more complex information set than that contained in the wholesale price of shrimp and the easily identifiable costs of storage. Additional factors may include the previous practice of the warehouse, the capacity of the warehousing firm, or existing marketing commitments. An attempt to treat these complexities would not likely be successful due to limitations of the theory and the data. The VAR model makes no attempt to model the complexities. Instead, it attempts to capture the essence of the economic phenomenon through the results the phenomenon produces.

The information gained from the VAR specification may have had its most substantial influence on the respecification of the SEM in the importance given the cold storage holdings behavioral equation. The VAR model appears to indicate that storage activity plays a major role in the market. Note that, according to the frequency-domain analysis, the storage variable is the leading variable in the short, 2.31-month cycle. Also, note (Appendix D) that the highest level of correlation between any two variables in the VAR model relates to the affect of storage on price. Although it would be impossible to quantify the effect of this information, it is safe to say that this knowledge, combined with exogenous knowledge pertaining to the operation of the market, contributed to the decision to specify the SEM with the storage equation performing a regulatory function.

This Chapter has presented the respecified SEM and discussed the utility of the VAR specification exercise in the respecification process. The hypothesis of no misspecification cannot be rejected in the case of the respecified model. This indicates that the respecified model can be considered a properly specified model by the modified Hausman test criterion. The analysis of the estimated parameters of the SEM provides evidence that the derived demand for shrimp at the wholesaler/retailer interface is elastic in the short run and inelastic in the long run. Also the response of imports to changes in the wholesale price or changes in the yen/dollar ratio appear to be inelastic. Analysis of a four equation version of the respecified SEM indicates that imports may be considered exogenous in a short-term model, i.e., a model based on monthly observations. Further analysis of the four equation model shows an elasticity of wholesale price with respect to imports that approaches unitary elasticity, viz, -.89.

These results have significant policy implications which are addressed in Chapter VIII.

# CHAPTER VIII
# SUMMARY AND CONCLUSIONS

This research was motivated by the realization that many existing econometric models may be misspecified and by a concern over the impacts on societal welfare of policies that might be based on such models. The motivation is strengthened by the notion that the demonstration of a tractable specification test will encourage the testing and improvement of econometric models to the benefit of society.

The misspecification test and the steps taken to respecify the econometric model have been demonstrated in the context of a study of the U.S. shrimp market. This chapter will review these techniques, discuss the analytical results and their policy implications, and close with a brief discussion of the benefits of this approach to developing an econometric model.

## Econometric Techniques

Of the several econometric techniques employed in this study, three are appropriate for discussion in this concluding chapter.

### Misspecification Test

The most novel econometric technique demonstrated in this study is the test of the general specification of a structural econometric model. The misspecification test used is a modification of a test developed by Hausman. The test is based on the existence of two estimators: one that is consistent under both the null and the alternative hypothesis and another that is efficient only if the null hypothesis that the model is properly specified cannot be rejected. The difference between the two estimators provides the basic data for the test. In his paper Hausman used the two and three stage least squares estimators in the misspecification test. Here the restricted and unrestricted reduced forms implied by the structural model were used. Since the unrestricted reduced form is relatively more independent of the specification being tested than is the two stage least squares estimator, it was hypothesized that this form of the test may be more powerful than the form proposed by Hausman.

The rejection of the null hypothesis provides the incentive for an effort to respecify the SEM in a manner that can be judged to be properly specified. Two approaches were taken. First, the restricted and unrestricted reduced forms of the model were utilized in a search for possible sources of misspecification in the existing model. Secondly, the model was specified in vector autoregressive (VAR) form and analyzed via frequency and time domain analysis techniques to gain insight into the relationships among the important variables in the market. These two approaches will be discussed in sequence.

### Reduced Forms

The use of alternative reduced forms of a SEM in locating possible sources of misspecification in a SEM entails comparing the unrestricted reduced form parameter estimates with the restricted reduced form parameter estimates. In this case, the restricted reduced form parameter estimates were derived from the 3SLS estimates of the structural parameters of the model. Under the theory that the unrestricted reduced form is consistent with the underlying population parameters, it is expected that as the sample size increases to infinity the unrestricted reduced form parameter estimates will converge to the true population parameter values. Thus, a large difference between the unrestricted reduced form and the restricted reduced form indicates a possible source of misspecification and suggests an area of the model that may require some alteration in a future specification.

### Frequency and Time Domain Analyses

A VAR model of the U.S. shrimp market was estimated by selecting a vector of endogenous variables based on theoretical and policy concerns. The order of the model was selected via an iterative process of adding to the model lags of the endogenous vector until the establishment of a white noise error process was confirmed using Hoskings' portmanteau test. Theoretical judgement indicated certain restrictions relating to one endogenous variable, the yen/dollar exchange ratio, should be placed on the model. These restrictions were tested using a maximum likelihood ratio test and found to be acceptable.

Once the VAR model was specified and estimated, its matrix of parameter estimates relating to the endogenous variables was decomposed, using the frequency and time dimension analysis techniques outlined by Chow, to estimate the lead/lag relationships among the variables of the endogenous vector. The variances of certain of these relationships were also calculated. The discovered relationships, along with the information gained from the specification analysis of the existing SEM of the market, were used in the respecification of the

SEM. The respecified model was subjected to the misspecification test and found to be properly specified by this criterion.

## Analytical Results

The misspecification test indicated that the Thompson et al. model was misspecified. A comparison of the unrestricted and restricted reduced forms of the model focused attention on the use of the fuel price variable and the trips equation as possible sources of misspecification. The VAR analysis suggested that, since the order of the VAR was selected to be two, the respecified SEM should include second degree lags of all endogenous and exogenous variables. The decomposition of the parameter matrix of the VAR provided several pieces of information regarding the relationship among the endogenous variables of the VAR. The most important of these relationships are

1. imports affect the wholesale price of shrimp in the short run;
2. over the long run imports respond to or are affected by the wholesale price;
3. landings lead wholesale price changes in the short-term, say, within a quarter of a year;
4. the yen/dollar ratio leads imports within a year.

The respecified SEM is based on the information gained during the analysis of the existing SEM and the VAR. The null hypothesis of proper specification could not be rejected in the case of the respecified SEM. The respecified SEM provides estimates of the structural relations among variables of interest in the U.S. shrimp market. The most important of these relationships include the response of wholesale price to changes in quantity of shrimp moved (sold) out of cold storage holdings and to changes in expenditures in eating places.

The structural relationships, in this case of a monthly model, indicate that price is inflexibly related to quantity sold in the short-term. This implies that relatively large changes in quantity can be sold with relatively small changes in price. Specifically, the price flexibility of demand was calculated to be -.29, implying that changes in quantity on the order of 3.5 percent would be expected to be associated with changes in price in the order of one percent. Note that because the quantity mentioned in this discussion is actually disappearance from cold storage, the price flexibility estimate applies to shrimp from any source: imports or landings.

The relationship between wholesale price and expenditures cannot be addressed with confidence since the t-value associated with the parameter on expenditures in the price equation was quite low. However, if this can be taken as evidence that this relationship is relatively small, it implies an inelastic relationship between wholesale price and expenditures. This implies that relatively large changes in expenditures will be expected to be associated with relatively small changes in price. The inelastic relationship between expenditures and price is supported by an analysis of the total elasticities derived from the structural parameter estimates. The total elasticity of price with respect to changes in expenditures was calculated to be -.45.

## Policy Implications

### Vector Autoregressive Model Policy Implications

The VAR analysis provides some insight into the functioning of the shrimp market. The finding that imports and wholesale price are related through a time distance of about three years may be an indication of the amount of time required for foreign producers to respond to price signals. This may have policy implications for both the domestic and foreign industries. These implications are particularly relevant to the expanding aquacultural production sector and the U.S. marketing sector.

It is expected that foreign suppliers will continue to make plans to increase production as long as the price they expect to receive for their production is greater than their total cost of production and distribution. The finding that price leads imports by three years indicates that the industry should factor in a three to six year lag into the development of their price expectations. Specifically, plans to construct new facilities must be based on an expected price that will be influenced by the increases in production that have been brought about by decisions made over the previous three years. Note that the impact of some of these decisions to increase production would not have been felt in the market in the current time period due to the delay between deciding to increase production and having that increase reach the market. Further, if the delay between the decision to build a new facility and the marketing of its first crop is on the order of three years, then the price to be used for planning will be one that is influenced by the changes in supply and demand which occur over a six year period.

Thus, decisions relating to the production and marketing of shrimp should consider the probable effects on supply and price of industry-wide decisions made over a six year period centered on the decision date. Such information should be helpful for both foreign and domestic production sectors and the U.S. marketing sector in planning their future investment programs. The information should also be useful for governmental policy makers in developing policies to address the problems and opportunities arising from this situation.

Once a facility begins producing, its responsiveness to price changes will be limited by its profit margin and its ability to shift into the production of different products. The high productivity of tropical shrimp farms (two crops per year are possible) and the high price of shrimp relative to other potential crops such as fish argue for a considerable amount of inertia or resistance to reducing supplies in the face of falling prices. The possibility of an inelastic supply response is supported by the finding that imported supplies of shrimp and wholesale price are related such that imports lead prices in the short term. This finding argues for a situation in which available supplies tend to be sold regardless of the price and stresses the degree of risk inherent in investment in expanded production.

A similar situation appears to exist in regard to the domestic shrimp production sector. The VAR analysis indicates that landings lead wholesale prices in the short term. Such a situation is potentially more damaging to the existing domestic production sector than it is to the existing foreign production sector. One would expect decreasing prices to result in decreased quantities supplied after some delay of, perhaps, three years. However, this may not be the case with the domestic sector since it is considered to be over capitalized presently.

A decrease in wholesale price will result in a decrease in exvessel price of approximately the same magnitude. Given the highly competitive, open-entry situation in the domestic production sector, the decrease in exvessel price implies a decrease in the number of fishing vessels. However, decreasing the number of operating vessels may not imply a corresponding decrease in the amount of shrimp landed. Catch per boat may increase and the total amount of shrimp landed may not change substantially. Ultimately, it may be expected that exvessel prices will equate very closely with aquacultured shrimp prices at an equivalent level in the production/distribution network. The degree by which this price is less than current exvessel prices is an indication of the degree of economic adjustment that will likely occur in the domestic production sector. The actual amount of adjustment will depend on the ability of the U.S. market to absorb substantial increases in quantity supplied without a corresponding decrease in price. In other words, the degree of adjustment will depend on the price and income elasticity of demand for shrimp.

With a substantial increase in supply and with the expectation that these increases will be sustained, it is possible that the intersection of supply and demand will occur in a more elastic section of the demand curve than has occurred in the past. This implies that much larger quantities of shrimp may be moved through the market without correspondingly large decreases in price. However, before this point is reached, it is likely that shrimp prices will continue to decline.

Given some probable decrease in exvessel prices and a related decrease in operating vessels, it may be appropriate to devise some program to assist the domestic production sector in adjusting to the changed conditions. The notion of compensation suggests that those who gain welfare from the decreased price of shrimp in the U.S. can be taxed to assist those who lose welfare as a result of the decrease in price. Given the high ratio of the value of total shrimp imports to the value of shrimp landings, it seems possible that a small tariff placed on imports would be sufficient to assist in the adjustment process without substantially disrupting the rate of increase in the flow of shrimp entering the U.S. Setting time limits on the operation of such a program and setting limits on the rate of decrease in prices should allow for a more orderly adjustment process than might otherwise result. At the same time, such a process should allow the benefits of increased production to be enjoyed by U.S. consumers.

### Simultaneous Equation Model Policy Implications

A comparison of the relationships between important variables estimated by the original SEM and the respecified SEM indicates some differences in implied policy recommendations. However, the differences are only in orders of magnitude and not in basic results. Specifically, both models indicate that the wholesale-level price elasticity of demand for shrimp is inelastic. Both models indicate the long-run or total flexibility of wholesale price with respect to expenditures is less than unitarily elastic. These results predict a decline in wholesale and exvessel shrimp prices in the absence of increases in expenditures sufficient to increase prices by an offsetting amount.

As an example policy environment, assume the current situation of increasing levels of imports and an open-entry, competitive harvesting sector. Assume that import quotas will be used to restrict marketed quantities enough to limit the decrease in price to one percent. The respecified model suggests that such restrictions may not have to be as stringent as those suggested by the original model to obtain the same policy goal.

For example, the respecified model suggests that, in the very short run, an additional 3.45 percent of quantity sold would result in a one percent decrease in price. The original SEM suggests that an increase of only .11 percent would cause a one percent decrease in price. However, if the price flexibility estimate of the respecified model is adjusted to reflect the existence of lagged endogenous variables in the price equation, the respecified model suggests that the quantity of shrimp moved per one percent decrease in wholesale price would be reduced to .52 percent. Thus, the respecified model would allow approximately five times the amount of increase in quantity moved than suggested by the original model, ceteris paribus.

The implications of the two models relating to expenditures are also different. Contrary to the implications relating to price flexibility in which the respecified model implied the more liberal expansion of quantity moved per one percent decrease in price, the expenditure flexibility implications of the original SEM are the more liberal of the two. The respecified model suggests that, in the long run, increases in expenditures of one percent would raise the price of shrimp by .45 percent in the long run; while the original SEM suggests that the price of shrimp would rise by one percent. This comparison should be tempered with the knowledge that the t-values associated with the expenditures variable in the respecified model indicated the parameters were insignificantly different from zero.

A comparison of the elasticity and flexibility estimates developed from the original and the respecified SEM is facilitated by Table 8.1 which displays these estimates.

Table 8.1
Elasticity and Flexibility Estimates of the Thompson et al. Model Compared with Similar Estimates from the Respecified SEM

| Structural Relationships | SEM1[a] | SEM2[a] | |
|---|---|---|---|
| | | Impact | Long Run[b] |
| %ΔConsumption/%ΔPrice | -.11 | -3.45[c] | -0.52[c] |
| %ΔConsumption/%ΔExpenditures | -0.42 | na | na |
| %ΔPrice/%ΔConsumption | -9.09[c] | -0.29 | -1.93 |
| %ΔPrice/%ΔImports | -0.37 | -0.20 | -1.33 |
| %ΔPrice/%ΔLandings | -0.007 | -0.11 | -0.73 |
| %ΔPrice/%ΔYen-dollar ratio | na | -0.08 | -0.53 |
| %ΔImports/%ΔYen-dollar ratio | na | +0.42 | +2.80 |

| Total Elasticity (from total multipliers) | SEM1 | SEM2 |
|---|---|---|
| %ΔPrice/%ΔExpenditures | +0.95 | +0.45 |
| %ΔPrice/%ΔYen-dollar ratio | -0.41 | -1.03 |
| %ΔImports/%ΔExpenditures | +0.36 | +0.04 |
| %ΔImports/%ΔYen-dollar ratio | +0.02 | +0.84 |

---

a SEM1 = the Thompson et al. model
a SEM2 = the respecified model
b implies the structural parameter has been adjusted to reflect the existence in the price equation of lagged values of the endogenous variable
c estimated by inversion

## The Benefits of This Approach to SEM Model Specification

The misspecification test demonstrated here appears to have potential as a tool for testing and stimulating the improvement of structural econometric models. Since it requires the estimation of the restricted and unrestricted reduced forms, it provides the ingredients for what proved to be the most productive specification diagnostic employed in this study: the comparison of the two reduced forms.

The estimation and analysis of the VAR specification did not prove to be as useful in the respecification of the SEM as expected. Much of the information it provided on the relationships among the variables in the model was unapplicable in the respecification of the SEM due to the inabilibty of current theory to explain the discovered relationships. However, the order of the VAR did provide guidance on the order of lags to be included in the SEM. Also, the relations between variables discovered through the frequency and time domain analysis provided some guidance in the respecification of the SEM.

## Concluding Remarks

The comparison of restricted and unrestricted reduced forms appears to be a useful technique for identifying possible sources of misspecification in a simultaneous equation model estimated with three stage least squares techniques. The misspecification test demonstrated here may be useful in providing some measure of confidence in the SEM specification selected to represent a given economic phenomenon. However, further investigation is required to understand the relationship between the misspecification test used here and the one discussed by Hausman since the two gave inconsistent results in the test conducted here. The vector autoregressive model and the accompanying frequency domain analysis demonstrated the VAR's ability to add to the understanding of the U.S. shrimp market by revealing the time related relationships among important variables. Finally, it is somewhat reassuring to be able to conclude that the policy implications of the existing econometric model of Thompson et al. appear to be quite robust in spite of the fact the null hypothesis of no misspecification was rejected.

# APPENDIX A

# SAS PROGRAM TO CONDUCT THE MISSPECIFICATION TEST ON THE THOMPSON ET AL. MODEL

```
//KMATRIX JOB (4001,1234,200,5),ZACH,CLASS=1,REGION=8000K
//  EXE      SAS
OPTIONS NOCENTER;
* MONTHLY SHRIMP DATA PROVIDED BY L.S.U. 1974:9 TO 1983:12 ;

DATA SHRIMP;  *SET UP THE DATA MATRIX;
INPUT Q2 Q3 Q4 AC PW PE S I L TR EX E R F PRSW PRSC PRSE PR TSW TSC
      TSE T @@;
*TRANSFORM THE DATA;
PW  = PW*.01;
PE  = PE*.01;
PE1 = LAG1(PE);
S1  = LAG1(S);
PW1 = LAG1(PW);
PW2 = LAG2(PW);
X2  = LAG2(EX);
PR2 = LAG2(PR);
T2  = LAG2(T);
*DESCRIBE THE VARIABLES;
LABEL
  AC = 'APPARENT CONSUMPTION'
  PW = 'WHOLESALE PRICE OF 26-30 COUNT SHRIMP'
  PE = 'EXVESSEL PRICE OF 26-30 COUNT SHRIMP'
  S  = 'COLD STORAGE HOLDINGS OF SHRIMP'
  I  = 'IMPORTS OF SHRIMP'
  L  = 'GULF LANDINGS OF SHRIMP'
  TR = 'NUMBER OF FISHING TRIPS'
  EX  = 'EXCHANGE RATE YEN PER DOLLAR'
  E  = 'EXPENDITURES IN RESTAURANTS'
  PR = 'AVERAGE PRECIPITATION'
  T  = 'AVERAGE TEMPERATURE';
*LOAD THE DATA;
CARDS;      /*INCLUDE KDATA JOB A1;
DATA ONES;  INPUT CONSTANT;   CARDS;     /*INCLUDE ONE SAS A1;
DATA SHRIMP1;      MERGE ONES SHRIMP;       DATA SHRIMP;
SET SHRIMP1 (FIRSTOBS = 3);
PROC MATRIX;     FETCH RDATA DATA = SHRIMP;  N=NROW(RDATA);
Y = RDATA(,5 6 7 8 9 10 11);
X = RDATA(,1 2 3 4 13 14 15 24 25 26 27 28 29 30);
CNY = 'AC' 'PW' 'PE' 'S' 'I' 'L' 'TR';
CNX = 'CONSTANT' 'Q2' 'Q3' 'Q4' 'E' 'R' 'F' 'PE1' 'S1' 'PW1' 'PW2'
 'EX2' 'PR2' 'T2';
```

```
*CALCULATE THE OLS STATISTICS;
BOLS =INV(X'*X)*X'*Y;     P = X * INV(X'*X)*X';     EOLS = Y - X*BOLS;
SIGOLS = EOLS'*EOLS#/N;         PRINT SIGOLS;
VARSUR = SIGOLS@INV(X'*X);    *SUR VARIANCE COVARIANCE MATRIX OF BOLS;
TVARSUR = VECDIAG(VARSUR);
STDEROLS = TVARSUR##.5;     * STANDARD ERRORS OF OLS PARAMETERS;

*2SLS AND 3SLS ANALYSIS;
Z1 = Y(,2)||X(,1 2 3 4 5);        *Z1 = PW C-Q4 E;
Z2 = Y(,1 3 5)||X(,1 2 3 4 8 9); *Z2 = AC PE I C-Q4 PE1 S1;
Z3 = Y(,2 6)||X(,1 2 3 4 6 10);  *Z3 = PW L C-Q4 R PW1;
Z4 = Y(,1 5 6)||X(,1 9);         *Z4 = AC I L C S1;
Z5 = X(,1 2 3 4 11 12);          *Z5 = C-Q4 PW2 EX2;
Z6 = Y(,7)||X(,1 2 3 4 13 14);   *Z6 = TR C-Q4 PR2 T2;
Z7 = Y(,3 6)||X(,1 2 3 4 7);     *Z7 = PE L C-Q4 F;
Z = BLOCK(Z1,Z2,Z3,Z4,Z5,Z6,Z7);
YVEC = Y(,1)//Y(,2)//Y(,3)//Y(,4)//Y(,5)//Y(,6)//Y(,7);
ID7 = I(7);      IDKX = ID7@X; IDKXX = ID7@INV(X'*X); IDKXP = ID7@X';
B2SLS  =  INV((Z'*IDKX)*IDKXX*(IDKXP*Z))*(Z'*IDKX)*IDKXX*(IDKXP*YVEC);
E2 = YVEC-Z*B2SLS;       *2SLS VECTOR OF ERROR TERMS;
EUV= (SHAPE(E2,110))';  * UNVECTED 2SLS ERRORS;
S2 = EUV'*EUV#/N;        * 2SLS SIGMA;    PRINT S2;
S2INV = INV(S2);       SKXX = S2INV@INV(X'*X);
PSI = INV((Z'*IDKX)*SKXX*(IDKXP*Z));
*PSI = COVARIANCE MATRIX OF 3SLS PARAMETER ESTIMATES;
TPSI = VECDIAG(PSI);  PRINT TPSI;  STDER3LS = TPSI##.5;
B3SLS = PSI*(Z'*IDKX)*SKXX*(IDKXP*YVEC);  B = B3SLS;
TAB3SLS = B3SLS||STDER3LS;  T3SN = 'B3SLS' 'STND ERROR';
PRINT TAB3SLS COLNAME=T3SN FORMAT=20.5;

*CALCULATE THE 3SLS REDUCED FORM PARAMETER ESTIMATES;
G = J(7,7,0);   *G IS THE GAMMA MATRIX PRECURSOR - 7 X 7 ZEROS;
D = J(14,7,0);  *D IS THE DELTA MATRIX PRECURSOR - 14 X 7 ZEROS;
* THE FOLLOWING STATEMENTS PUT THE PARAMETERS INTO THE G & D MATRICES;
*EQUATION 1;
D(3,1)=B(4,1);     D(4,1)=B(5,1); D(5,1)=B(6,1);
*EQUATION 2;
G(1,1)  =  -1;  G(2,1)=B(1,1);  D(1,1)=B(2,1);  D(2,1)=B(3,1);
G(1,2)=B(7,1); G(2,2)=-1; G(3,2)=B(8,1); G(5,2)=B(9,1); D(1,2)=B(10,1);
D(2,2)=B(11,1);  D(3,2)=B(12,1);  D(4,2)=B(13,1);  D(8,2)=B(14,1);
D(9,2)=B(15,1);
*EQUATION 3;
G(2,3)=B(16,1);  G(3,3)=-1;  G(6,3)=B(17,1);  D(1,3)=B(18,1);
D(2,3)=B(19,1);  D(3,3)=B(20,1);  D(4,3)=B(21,1);  D(6,3)=B(22,1);
D(10,3)=B(23,1);
*EQUATION 4;
G(1,4)=B(24,1);  G(4,4)=-1;  G(5,4)=B(25,1);  G(6,4)=B(26,1);
D(1,4)=B(27,1); D(9,4)=B(28,1);
*EQUATION 5;
G(5,5)=-1;  D(1,5)=B(29,1);  D(2,5)=B(30,1);  D(3,5)=B(31,1);
D(4,5)=B(32,1); D(11,5)=B(33,1); D(12,5)=B(34,1);
```

```
*EQUATION 6;
G(6,6)=-1;   G(7,6)=B(35,1);   D(1,6)=B(36,1);   D(2,6)=B(37,1);
D(3,6)=B(38,1); D(4,6)=B(39,1); D(13,6)=B(40,1); D(14,6)=B(41,1);
*EQUATION 7;
G(3,7)=B(42,1);   G(6,7)=B(43,1);   G(7,7)=-1;   D(1,7)=B(44,1);
D(2,7)=B(45,1); D(3,7)=B(46,1); D(4,7)=B(47,1); D(7,7)=B(48,1);
RF = -D*INV(G);  RF = THE 3SLS REDUCED FORM;    PRINT RF;

*CALCULATE THE VARIANCES OF THE REDUCED FORM PARAMETER ESTIMATES USING
PETER SCHMIDT'S TECHNIQUE;
XX = INV(X'*X);
*W1;
RF1 = RF(,2); X1 = X(,1 2 3 4 5); H1 = XX*X'*X1; W1 = RF1||H1;
*W2;
RF2 = RF(,1 3 5); X2 = X(,1 2 3 4 8 9); H2 = XX*X'*X2; W2 = RF2||H2;
*W3;
RF3 = RF(,2 6); X3 = X(,1 2 3 4 6 10); H3 = XX*X'*X3;
W3 = RF3||H3;
*W4;
RF4 = RF(,1 5 6); X4 = X(,1 9); H4 = XX*X'*X4; W4 = RF4||H4;
*W5;
X5 = X(,1 2 3 4 11 12); W5 = XX*X'*X5;
*W6;
RF6 = RF(,7); X6 = X(,1 2 3 4 13 14); H6 = XX*X'*X6;
W6 = RF6||H6;
*W7;
RF7 = RF(,3 6); X7 = X(,1 2 3 4 7); H7 = XX*X'*X7;
W7 = RF7||H7;
W = BLOCK(W1,W2,W3,W4,W5,W6,W7);        ID14 = I(14);
DKI = (INV(G))'@ID14;
VARRF = DKI*W*PSI*W'*DKI';  *VARIANCE OF 3SLS REDUCED FORM PARAMETERS;
SS = VECDIAG(VARRF);
STNDERRF = SS##.5;   *STANDARD ERROR OF THE REDUCED FORM PARAMETERS;
*HAUSMAN TEST;
VBOLS = SHAPE(BOLS',1);  * VECTED OLS PARAMETER MATRIX;
VRF   = SHAPE(RF',1);    * VECTED REDUCED FORM PARAMETER MATRIX;
Q = VBOLS-VRF;        VARQ = VARSUR-VARRF;     IVQ = INV(VARQ);
M = Q'*IVQ*Q;  PRINT M;  *HAUSMAN TEST STATISTIC;
TRF = VRF#/STNDERRF;      TOLS = VBOLS#/STDEROLS;
TABLE = VRF||STNDERRF||TRF||VBOLS||STDEROLS||TOLS;
TABLEN = 'VECRF' 'STND ER RF' 'TRF' 'VECBOLS' 'STND ER OLS' 'TOLS';
PRINT TABLE COLNAME=TABLEN FORMAT=15.8;
*HAUSMAN TEST TWO (USES HAUSMAN'S ORIGINAL DEFINITION);
DIAGS2 = INV(ID7 # S2);       JJJ = DIAGS2 @ P;
VAR2SB = INV(Z'*(JJJ) * Z);
VAR3SB = PSI;   VARQ1 = VAR2SB-VAR3SB;       IVQ1 = INV(VARQ1);
Q1 = B2SLS-B3SLS;
M1 = Q1'*IVQ1*Q1; PRINT M1;
LIST;
/*
```

# APPENDIX B

## PROGRAM TO ESTIMATE THE VAR MODEL AND ANALYZE ITS PARAMETER MATRIX

This is the Gauss program used in estimating and analyzing the VAR model of the U.S. shrimp industry. Explanatory comments, indicated by @, have been added.

```
@ These first five lines explain the data and indicate where the output
will be filed.@
Output file=vart1119.out reset;
?"Output of VARTrig.119 11/19/87.  S=landings, imports, prices,
storage, and yen/$ rate. No lagged expenditures are included.
Cold storage data are end-of-period figures.
Data are from (40 - 210). 14 years.  k=3."; ?;

@ Load and transform the data. @
load s[210,18]=zdata.3;
s=s[40:210,3 4 7 11 18 12 13 9]; t=rows(s); s[.,6]=s[2:t,6]|35281;
s[.,1 2 6 7]=.001*s[.,1 2 6 7];  s[.,3 7]=100*s[.,3 7]./s[.,5];
@ The data in s are 1.landings, 2. imports, 3. price, 4. Yen/$ rate,
5. GNP implicit price deflator, 6. cold storage, 7. expenditures,
8. P.P.I. @
s=s[.,1 2 3 6 4 7];
@The data in s are now 1. landings, 2. imports, 3. price, 4. cold
storage, 5. yen/$, 6. deflated restaurant expenditures *.001.@

exr=s[.,6]; s=s[.,1:5]; t=rows(s); ?"# Observations A " t; k=3;
ivs=(s[k,.]~s[k-1,.])';
@ivs=the initial values of the s vector. This must be changed to
reflect the number of lags in the system.@

@ The following lines set up the lags of the variables, creates the
dummy variables, and concatenates these into the predetermined variable
vector, X. @
s1=s[k:t-1,.];  s2=s[k-1:t-2,.];  s3=s[k-2:t-3,.];
ex=exr[k+1:t,.]; ex1=exr[k:t-1,.]; s=s[k+1:t,.];
t=rows(s); tt=ones(t,1); tr=seqa(1,1,t); dv=ones(20,1).*.eye(12);
dv=dv[1:t,2:12]; dv=tt~tr~dv~ex[1:t,.];  dr=cols(dv);
dvr=cols(dv)-2;
x=dv~s1~s2; vv=2; k=cols(x); m=cols(s);  mk=m*k;

@ Calculate the ordinary least squares estimate of the VAR parameters
and their associated t-values. @
xnx=invpd(x'x); b=xnx*x'*s; e=s-x*b; sig=e'e./t;
xnxdv=xnx[1:14,1:14]; cdv=sig.*.xnxdv;
xnxs=xnx[15:24,15:24]; c1=sig.*.xnxs;
```

```
sedv=sqrt(diag(cdv));
sedv1=abs(sedv).< 1e-10; sedv=sedv+(sedv1.*1e-10);
sedv=(reshape(sedv,5,14))';
seb=sqrt(diag(c1));  v1=seb.< 1e-10;
seb=seb+(v1.*1e-10);
seb=(reshape(seb,5,10))';
se1=sedv|seb;  rpt=b./se1;
?; ?"Unrestricted Parameter Estimates and t-Values";
format /m1 /rd 8,4;
?;  rpt1=b[.,1]~rpt[.,1];  rpt2=b[.,2]~rpt[.,2];
    rpt3=b[.,3]~rpt[.,3];
    rpt4=b[.,4]~rpt[.,4]~b[.,5]~rpt[.,5];
    rptv=rpt1~rpt2~rpt3~rpt4;  rptv;

@ Calculate the restricted estimates of the VAR parameters and
associated t-values. @
b=reshape(b',mk,1);  btt=rows(b);
let r5[4,5]= 1 0 0 0 0  0 1 0 0 0  0 0 1 0 0  0 0 0 1 0;
z5=zeros(4,5); r12=eye(12);
rt=zeros(20,96);  r=zeros(8,14)~((r5~z5)|(z5~r5));
r=r|(zeros(12,2)~r12~zeros(12,10));
rr=rt~r;
c=sig[.,m].*.xnx;   bb=btt-k+1;
br=b-c*r'*invpd(rr*c*r')*(r*b[bb:btt,.]);    format /m3 /rd 8,4;
?"=======br'" br';
bt=reshape(br,m,k);
xnxdv=xnx[1:14,1:14]; cdv=sig.*.xnxdv;
xnx=xnx[15:24,15:24]; c=sig.*.xnx;
r=zeros(8,40)~((r5~z5)|(z5~r5));
sedv=sqrt(diag(cdv)); ?"sedv=(sqrt(diag(cdv))'" sedv';
@ The following line replaces any zero standard error with a small
number. @
sedv1=abs(sedv).< 1e-10; sedv=sedv+(sedv1.*1e-10); @ Replace zero
sedv=(reshape(sedv,5,14))';  ?; ?"sedv=====" sedv;
varbr1=c-c*r'invpd(r*c*r')*r*c;     @ save leav=varbr1; @
varbr1=diag(varbr1);  v1=varbr1.< 1e-10;
varbr1=varbr1+(v1.*1e-10); se=sqrt(varbr1); ?;
?"se=(sqrt(varbr1))" se';
 se=(reshape(se,5,10))'; ?; ?"se'======" se';
se1=sedv|se;  rpt=bt'./se1;
?; ?"Restricted Parameter Estimates and t-Values";
format /m1 /rd 8,4;        bt=bt';
?;  rpt1=bt[.,1]~rpt[.,1];  rpt2=bt[.,2]~rpt[.,2];
    rpt3=bt[.,3]~rpt[.,3];
    rpt4=bt[.,4]~rpt[.,4]~bt[.,5]~rpt[.,5];
    rptv=rpt1~rpt2~rpt3~rpt4;  rptv;    bt=bt';

@ The following lines test the significance of the restrictions placed
on the parameters of the VAR via a maximum likelihood ratio test. @
ls=ln(det(sig));
?; ? "LS ln(det(sigma) " ls; ?;
er=s-x*bt'; sigr=er'er./t; varb=sigr[.,m].*.diag(xnx);
```

```
@se=sqrt(varb);@
rls=ln(det(sigr));
?; ? "RLS ln(det(sigma)) " ln(det(sigr));
?"Cdfchic RLS-LS " cdfchic((t*(rls-ls)),((vv*m)+dvr));

@ The following lines test the hypothesis that the error vector of the
VAR is a white noise process. @
si=invpd(sigr); s=0;
j=1; do until j > 20; r=er[j+1:t,.]; rk=er[1:t-j,.]; ck=rk'r./t;
 s=s+sumc(diag(ck'si*ck*si)); j=j+1; endo; p=t*s;
?; ? "Hoskings test  " p; ?"Number of observations " t;
?"Degrees of Freedom  " (20-vv)*m^2;
y=cdfchic(p, ((20-vv)*m^2));  ?"Chi-square statistic " y;

clear s, s1, s2, s3, tt, tr, dv;

@ The following section calculates the autocovariance matrix of the VAR
as in Chow, p. 53.@
b=bt'; dr=dr+1; zm=zeros(m,m); @ dr is the cols(dv).  @
a=(b[dr:k,.]')|(eye(m)~zm); v=(sig~zm)|zeros(5,10);
g=zeros(5,5); format /m3 /rd 14,6;
j=1; gz=v; am=a; at=a'; do until j > 200; gz=gz+am*v*at; am=a*am;
at=a'*at; j=j+1; endo; gz5=gz;
var=diag(gz5[1:m,1:m]); sd=sqrt(var*var');   ? gz5[1:m,1:m]./sd;
an=14; @ an is the # of autocorrelation matrices to be considered.@
gg=(gz5[1:m,1:m]./sd); ja=1; do until ja > an;
gz5=a*gz5; ? gz5[1:m,1:m]./sd; gg=gg|(gz5[1:m,1:m]./sd); ja=ja+1; endo;
gg[1:5,.]=(ones(5,5)-eye(5)).*gg[1:5,.];
save leagg1=gg;
@gg1 is the series of autocovariance matrices out to a lag of 14.  gg1
has not been transformed such that the covariances are approximately
normally distributed. @
?" gg1 = " gg;
gg=.5*ln((1+gg)./(1-gg));  save leagg=gg;
@ gg is the transformed gg1 series such that the statistics have a
normal distribution. @

@ The following lines calculate the mathematical derivatives of the
covariances with respect to a change in the parameter estimates. @
br=vec(b[15:24,.]);  g1=g; g2=g; g3=g; g4=g; g5=g; g6=g; g7=g; g8=g;
g9=g; g10=g; g11=g; g12=g; g13=g; g14=g;
jj=1; do until jj > 50.1; b=br; dd=maxc((.001*br[jj,1])|(1e-6));
b[jj,1]=b[jj,1]+dd; b=reshape(b,5,10);
                         ? "Iteration  " jj;
zm=zeros(m,m); a=(b)|(eye(m)~zm); v=(sig~zm)|zeros(5,10);
 j=1; gz=v; am=a; at=a'; do until j > 200; gz=gz+am*v*at; am=a*am;
at=a'*at; j=j+1; endo; gz5=gz[1:m,1:m]; d=diag(gz5); d=sqrt(d*d');
g0=gz5./d;   ja=1; do until ja > an;
@ an is # of autocorrelation matrices to be considered.@
gz=a*gz; g0=g0|(gz[1:m,1:m]./d); ja=ja+1; endo;
g0[1:5,.]=(ones(5,5)-eye(5)).*g0[1:5,.]; g0=.5*ln((1+g0)./(1-g0));
 g0=(g0-gg)./dd; g=g|g0[1:5,.];
```

```
g1=g1|g0[6:10,.];   g4=g4|g0[21:25,.];   g5=g5|g0[26:30,.];
g6=g6|g0[31:35,.];
g2=g2|g0[11:15,.];   g3=g3|g0[16:20,.];   g7=g7|g0[36:40,.];
g8=g8|g0[41:45,.];
g9=g9|g0[46:50,.]; g10=g10|g0[51:55,.]; g11=g11|g0[56:60,.];
g12=g12|g0[61:65,.];  g13=g13|g0[66:70,.]; g14=g14|g0[71:75,.];
jj=jj+1; endo; gr=rows(g);
clear  v, am, at, gz, gz5, d, x;

g0=g[6:gr,.]; g1=g1[6:gr,.]; g2=g2[6:gr,.];
g3=g3[6:gr,.]; g4=g4[6:gr,.]; g5=g5[6:gr,.];
g6=g6[6:gr,.]; g7=g7[6:gr,.]; g8=g8[6:gr,.];
g9=g9[6:gr,.]; g10=g10[6:gr,.]; g11=g11[6:gr,.]; g12=g12[6:gr,.];
g13=g13[6:gr,.]; g14=g14[6:gr,.];
save  leag0=g0;  save  leag1=g1;  save  leag2=g2;  save  leag3=g3;  save
leag4=g4;
save  leag5=g5;  save  leag6=g6;  save  leag7=g7;  save  leag8=g8;  save
leag9=g9;
save leag10=g10; save leag11=g11; save leag12=g12; save leag13=g13;
save leag14=g14;

@ At  this  point  another  program  calculates  the  variance/covariance
matrices of the autocorrelation matrices. @

@The  following  section  derives  the  lead/lag  relationships  via  the
trigonometric method of Chow@
format /m3 /rd 10,4;
kk=rows(a); nm=zeros(kk,kk); nv=zeros(kk,1);
bc="bc"; zc="zc"; c="c"; w="w"; clear bcr, bci, zcr, zci, y, cr, ci, r,
wr, wi; dv=ivs; @ivs=initial values of the S vector.@
y=eig(a,bc); @Calculate and print eigenvalues@  ?; ? "Eigenvalues";  y;
@ Calculate  the  canonical  variables,  Z0=inv(B)Y0.   Note  the  procedure
cmsoln  solves  the  problem  BZ0=Y0  for  Z0.   Here  the  value  of  Z0  is
obtained without first detemining inv(B).@
r=cmsoln(bcr,bci,dv,nv,zc);

@ Calculate  the  phase  complex  conjugates,  Ph=BZ0.  Note  Y=BDZ0  is  the
sum  of  the  complex  conjugates  associated  with  the  phase  angles
multiplied  by  the  associated  complex  conjugates  of  the  eigen  values.
Here  we  only  calculate  the  complex  values  from  which  we  derive  the
phase angles.@
r=cmemult(bcr,bci,zcr',zci',c); ?; ? "Phase conjugates";

@ The  following  lines  deletes  those  portions  of  the  eigen  value  vector
that  have  non-positive  imaginary  parts  by  returning  a  zero  for  the
negative  complex  conjugates  and  for  the  non-complex  roots.   This  allows
the  analysis  to  consider  only  the  complex  conjugates  with  positive
imaginary  parts  and  avoids  the  duplication  that  would  be  involved  if
the complex conjugates with negative values were allowed to remain.  @
j=1;  rd=zeros(kk,1);
do until  j  >  (kk+.1);  if  abs(y[j,2])  .>  (1e-12);  rd[j,1]=1;  j=j+1;
endif; j=j+1; endo; y=rd.*y;
```

```
@ The following line preserves only those elements of the phase
conjugate matrices that correspond to those elements of the eigen value
vector that have a positive imaginary term.  Again this is to avoid
duplication of the calculation of the phase angle.  Otherwise, we would
calculate the phase angle for both conjugates:  the one with the real
value and the one with the imaginary value.  The matrix is also
squeezed or packed to eliminate the blank spaces.@
crs=cr.*rd'; cis=ci.*rd';  crs=packr(miss(crs,0)')';  ct=rows(crs);
cis=packr(miss(cis,0)')'; ct=rows(cis); cc=cols(cis);
@ The following lines replaces values which approach zero with zero.@
cc=cols(crs); dt=abs(crs) .< 1e-10; dt=ones(ct,cc)-dt; crs=dt.*crs;
dt=abs(cis) .< 1e-10; dt=ones(ct,cc)-dt; cis=dt.*cis;
clear dt, ct, cc;
@ The following line replaces zero values in the real part of the
conjugate with a one so that the phase angle calculation process on the
next line can be defined even in the case where both cri and crs are
zero. @
dt = crs .== 0; crs=crs+dt;
@ Calculate the phase angles. @
phang=arctan(cis./crs);
@ The following lines determine if both the real and imaginary parts of
a complex conjugate are negative.  @
drs=crs.< 0; dis=cis.< 0;
d3=drs+dis; d3s=d3.==2;
@ Adjust the value and sign of the phase angle to reflect which quarter
of the circle in which it occurs.  First, Pi is added to the phase
angle value if the real component is negative, i.e., if the angle is in
the second or third quadrants.  Then 2Pi is substracted if both
imaginary and real values are negative, i.e., the angle is in the third
quardrant.  @
phang=phang+drs*pi-2*pi*d3s;
phang=phang[1:m,.];
?;  ?"Phase Angles " phang; @ Print phase angles. @
@ Calculate frequency angles.@
y=packr(miss(y,0))'; ang=arctan(y[2,.]./y[1,.]);
@ Adjust value of the frequency angle if the real component is
negative, i.e., the angle is in the second quadrant. @
dang=y[1,.].<0; ang=ang+dang*pi;
?; ?"Frequency Angles" ang;  @ Print frequency angles. @
?; ?"  Cycle Lengths  "; c=(2*pi)./ang; c;
ztau=(1./ang).*phang;
?;  ?"ZTau: Lead-Lag Relationships" ztau;   @ Print lead-lag
relationships. End of program. @
```

# APPENDIX C
## SAS PROC MATRIX TO SELECT THE ORDER OF THE VAR MODEL

```
//ZMATRIX JOB(4001,1234,50,5),ZACH,CLASS=1,MSGLEVEL=(0,0),REGION=5000K
//  EXEC SAS
OPTIONS NOCENTER;
* MONTHLY SHRIMP DATA PROVIDED BY NMFS AND OTHERS 1973:7 TO 1986:6;

* LOAD DATA;
  DATA SHRIMP;
       INPUT TR BCS L I AC PE P DI PPI POP YS ST EX APR
             ATP IR CPI GNP;
  P   = (P/GNP)*100;
  EXR = (EX/GNP)*100;
  L   = L*.001;
  I   = I*.001;
  ST = ST*.001;
  EXR= EXR*.001;
  LABEL  TR = 'TREND VARIABLE'
          L = 'LANDINGS OF SHRIMP'
          I = 'IMPORTS OF SHRIMP'
          P = 'WHOLESALE PRICE OF SHRIMP'
         YS = 'YEN/DOLLAR RATIO'
         ST = 'COLD STORAGE HOLDINGS OF SHRIMP'
        EXR = 'EXPENDITURES IN RESTAURANTS'
        GNP = 'GNP PRICE DEFLATOR';
CARDS;
;;;;
PROC PRINT;
DATA SHRIMP1;
     SET SHRIMP (FIRSTOBS=29 OBS=210);
PROC MATRIX;
   FETCH S DATA = SHRIMP1; T=NROW(S);
   TR=S(,1)-22; EXR=S(,13); S=S(,3 4 7 11 12);

* THE FOLLOWING LINE CONVERTS THE STORAGE DATA INTO END-OF-MONTH
FIGURES;
S(,5)=S(2:T,5)//35.281;
T=NROW(S); K=NCOL(S); M=14;
PRINT S;
```

```
* SET UP LAGS OF THE DATA;
S1=S(M:T-1,); S2=S(M-1:T-2,); S3=S(M-2:T-3,); S4=S(M-3:T-4,);
S5=S(M-4:T-5,); S6=S(M-5:T-6,); S7=S(M-6:T-7,); S8=S(M-7:T-8,);
S9=S(M-8:T-9,); S10=S(M-9:T-10,); S11=S(M-10:T-11,);
S12=S(M-11:T-12,); S13=S(M-12:T-13,); S14=S(M-13:T-14,);
EX=EXR(M+1:T,); EX1=EXR(M:T-1,); S=S(M+1:T,); T=NROW(S); TT=J(T,1,1);

* SET UP THE INTERCEPT, TREND, DUMMY VARIABLES AND EXPENDITURES AS THE
"B" SECTION OF THE MODEL:  Y=B+AY1;
DV=J(20,1); ID=I(12); DV=DV@ID; DV=TT||TR(1:T,)||DV(1:T,2:12)||EX;

* THIS SECTION IS A "DO LOOP" WHICH SEQUENTIALLY ADDS ANOTHER LAG OF
THE ENDOGENOUS VECTOR TO THE PREDETERMINED VECTOR AND CALCULATES THE
LOG OF THE DETERMINANT OF THE ERROR COVARIANCE MATRIX.  THESE VALUES
ARE THEN ACCUMULATED INTO A VECTOR.;
DCOL=1 1;
JJ=1; X=DV||S1; LINK CALC;
X=DV||S1||S2; LINK CALC;
X=DV||S1||S2||S3; LINK CALC;
X=DV||S1||S2||S3||S4; LINK CALC;
X=DV||S1||S2||S3||S4||S5; LINK CALC;
X=DV||S1||S2||S3||S4||S5||S6; LINK CALC;
X=DV||S1||S2||S3||S4||S5||S6||S7; LINK CALC;
X=DV||S1||S2||S3||S4||S5||S6||S7||S8; LINK CALC;
X=DV||S1||S2||S3||S4||S5||S6||S7||S8||S9; LINK CALC;
X=DV||S1||S2||S3||S4||S5||S6||S7||S8||S9||S10; LINK CALC;
X=DV||S1||S2||S3||S4||S5||S6||S7||S8||S9||S10||S11; LINK CALC;
X=DV||S1||S2||S3||S4||S5||S6||S7||S8||S9||S10||S11||S12; LINK CALC;
X=DV||S1||S2||S3||S4||S5||S6||S7||S8||S9||S10||S11||S12||S13;
LINK CALC;
X=DV||S1||S2||S3||S4||S5||S6||S7||S8||S9||S10||S11||S12||S13||S14;
LINK CALC; LINK CONTINUE; CALC:
XX=INV(X'*X); B=XX*X'*S; E=S-X*B; SIG=(E'*E)#/T; LDET=LOG(DET(SIG));
   DROW=JJ||LDET; DCOL=DCOL//DROW; JJ=JJ+1; RETURN; CONTINUE:

* CALCULATE THE RESULTING SERIES OF LIKELIHOOD RATIO STATISTICS.;
V =NROW(DCOL); R=T*(DCOL(2:V-1,2)-DCOL(3:V,2));
PRINT DCOL; PRINT R; PRINT T;
LIST;
RETURN;
```

Note: t=168.

# APPENDIX D
# AUTOCORRELATIONS AMONG VARIABLES IN THE VAR VECTOR AND ASSOCIATED Z-VALUES

### Contemporaneous Correlations

| | Autocorrelations | | | | | Z-Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L | I | P | S | Y/$ | L | I | P | S | Y/$ |
| Landings | 1.0000 | 0.0174 | -0.1959 | 0.2948 | -0.0177 | | 0.1913 | -1.3579 | 2.4211 | -0.1154 |
| Imports | 0.0174 | 1.0000 | -0.0594 | -0.0118 | 0.2546 | 0.1913 | | -0.3185 | -0.0920 | 1.5083 |
| Price | -0.1959 | -0.0594 | 1.0000 | -0.2449 | -0.3302 | -1.3579 | -0.3185 | | -1.6758 | -1.7083 |
| Storage | 0.2948 | -0.0118 | -0.2449 | 1.0000 | -0.1016 | 2.4211 | -0.0920 | -1.6758 | | -0.6413 |
| Yen/$ | -0.0177 | 0.2546 | -0.3302 | -0.1016 | 1.0000 | -0.1154 | 1.5083 | -1.7083 | -0.6413 | |

### Autocorrelations at One Month Lag

| | Autocorrelations | | | | | Z-Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L | I | P | S | Y/$ | L | I | P | S | Y/$ |
| Landings | 0.5805 | 0.0921 | -0.1679 | 0.1982 | -0.0304 | 6.8249 | 0.8793 | -1.1207 | 1.5300 | -0.1899 |
| Imports | -0.0120 | 0.5633 | -0.0313 | -0.1103 | 0.3039 | -0.1106 | 5.4148 | -0.1632 | -0.8305 | 1.8225 |
| Price | -0.2409 | -0.0797 | 0.9310 | -0.3461 | -0.3576 | -1.6916 | -0.4346 | 10.7252 | -2.2659 | -1.8220 |
| Storage | 0.3548 | 0.1093 | -0.1178 | 0.9296 | -0.1070 | 2.9085 | 0.8503 | -0.8208 | 12.2655 | -0.6480 |
| Yen/$ | -0.0156 | 0.2387 | -0.3136 | -0.0968 | 0.9624 | -0.1066 | 1.4410 | -1.6579 | -0.6374 | 7.3694 |

### Autocorrelations at Two Month Lag

| | Autocorrelations | | | | | Z-Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L | I | P | S | Y/$ | L | I | P | S | Y/$ |
| Landings | 0.3594 | 0.1115 | -0.1386 | 0.1293 | -0.0370 | 3.6149 | 1.0337 | -0.9076 | 0.9501 | -0.2265 |
| Imports | -0.1111 | 0.4891 | -0.0204 | -0.1603 | 0.3285 | -1.0330 | 4.5424 | -0.1064 | -1.2121 | 1.9818 |
| Price | -0.2407 | -0.0917 | 0.8674 | -0.4349 | -0.3796 | -1.7017 | -0.5139 | 9.0850 | -2.6816 | -1.8980 |
| Storage | 0.3508 | 0.1866 | 0.0048 | 0.8403 | -0.1124 | 2.8328 | 1.4238 | 0.0330 | 10.0081 | -0.6577 |
| Yen/$ | -0.0147 | 0.2271 | -0.2987 | -0.0922 | 0.9183 | -0.1056 | 1.4029 | -1.6147 | -0.6336 | 5.8164 |

### Autocorrelations at Three Month Lag

| | Autocorrelations | | | | | Z-Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L | I | P | S | Y/$ | L | I | P | S | Y/$ |
| Landings | 0.2144 | 0.1066 | -0.1188 | 0.0909 | -0.0332 | 2.2568 | 1.0886 | -0.7792 | 0.6523 | -0.2028 |
| Imports | -0.1251 | 0.3368 | -0.0217 | -0.1947 | 0.3443 | -1.1760 | 3.4566 | -0.1138 | -1.3894 | 2.0962 |
| Price | -0.2561 | -0.1261 | 0.7894 | -0.5006 | -0.3938 | -1.8591 | -0.7384 | 7.4902 | -2.9034 | -1.9275 |
| Storage | 0.3154 | 0.2406 | 0.1147 | 0.7263 | -0.1178 | 2.5453 | 1.7939 | 0.7647 | 7.7848 | -0.6716 |
| Yen/$ | -0.0140 | 0.2164 | -0.2847 | -0.0879 | 0.8754 | -0.1055 | 1.3686 | -1.5724 | -0.6298 | 4.9531 |

Autocorrelations at Four Month Lag

| | Autocorralations | | | | | Z-Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L | I | P | S | Y/$ | L | I | P | S | Y/$ |
| Landings | 0.1283 | 0.0925 | -0.1035 | 0.0688 | -0.0247 | 1.4989 | 1.0544 | -0.6912 | 0.4934 | -0.1526 |
| Imports | -0.1359 | 0.2537 | -0.0297 | -0.2078 | 0.3499 | -1.3660 | 2.6287 | -0.1598 | -1.4684 | 2.1518 |
| Price | -0.2681 | -0.1592 | 0.7036 | -0.5440 | -0.4022 | -2.0247 | -0.9818 | 6.0458 | -3.0035 | -1.9279 |
| Storage | 0.2643 | 0.2693 | 0.2102 | 0.6005 | -0.1227 | 2.1724 | 1.9710 | 1.3411 | 5.8826 | -0.6873 |
| Yen/$ | -0.0133 | 0.2062 | -0.2713 | -0.0838 | 0.8343 | -0.1055 | 1.3352 | -1.5305 | -0.6258 | 4.3754 |

Autocorrelations at Five Month Lag

| | Autocorrelations | | | | | Z-Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L | I | P | S | Y/$ | L | I | P | S | Y/$ |
| Landings | 0.0779 | 0.0761 | -0.0912 | 0.0575 | -0.0150 | 1.0157 | 1.0002 | -0.6274 | 0.4225 | -0.0943 |
| Imports | -0.1293 | 0.1793 | -0.0425 | -0.2101 | 0.3492 | -1.4078 | 1.8907 | -0.2371 | -1.4960 | 2.1754 |
| Price | -0.2733 | -0.1949 | 0.6125 | -0.5649 | -0.4053 | -2.1648 | -1.2785 | 4.7716 | -3.0398 | -1.9064 |
| Storage | 0.2053 | 0.2773 | 0.2890 | 0.4704 | -0.1271 | 1.7504 | 2.0269 | 1.7615 | 4.2767 | -0.7052 |
| Yen/$ | -0.0127 | 0.1965 | -0.2586 | -0.0799 | 0.7952 | -0.1055 | 1.3025 | -1.4891 | -0.6217 | 3.9470 |

Autocorrelations at Six Month Lag

| | Autocorrelations | | | | | Z-Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L | I | P | S | Y/$ | L | I | P | S | Y/$ |
| Landings | 0.0494 | 0.0615 | -0.0806 | 0.0524 | -0.0059 | 0.7057 | 0.9057 | -0.5763 | 0.4025 | -0.0378 |
| Imports | -0.1188 | 0.1285 | -0.0574 | -0.2031 | 0.3437 | -1.3773 | 1.3492 | -0.3347 | -1.4796 | 2.1699 |
| Price | -0.2708 | -0.2271 | 0.5191 | -0.5646 | -0.4040 | -2.2596 | -1.5910 | 3.6798 | -3.0468 | -1.8706 |
| Storage | 0.1446 | 0.2685 | 0.3502 | 0.3420 | -0.1310 | 1.2982 | 1.9960 | 2.0539 | 2.9261 | -0.7264 |
| Yen/$ | -0.0121 | 0.1873 | -0.2465 | -0.0761 | 0.7579 | -0.1055 | 1.2704 | -1.4485 | -0.6175 | 3.6089 |

Autocorrelations at Seven Month Lag

| | Autocorrelations | | | | | Z-Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L | I | P | S | Y/$ | L | I | P | S | Y/$ |
| Landings | 0.0341 | 0.0498 | -0.0710 | 0.0505 | 0.0019 | 0.5271 | 0.7932 | -0.5307 | 0.4125 | 0.0125 |
| Imports | -0.1047 | 0.0899 | -0.0728 | -0.1901 | 0.3351 | -1.2828 | 0.9293 | -0.4479 | -1.4370 | 2.1446 |
| Price | -0.2602 | -0.2545 | 0.4262 | -0.5457 | -0.3990 | -2.2922 | -1.9077 | 2.7662 | -3.0294 | -1.8254 |
| Storage | 0.0862 | 0.2467 | 0.3939 | 0.2201 | -0.1346 | 0.8234 | 1.9000 | 2.2525 | 1.7948 | -0.7515 |
| Yen/$ | -0.0116 | 0.1785 | -0.2349 | -0.0725 | 0.7224 | -0.1055 | 1.2391 | -1.4089 | -0.6132 | 3.3314 |

Autocorrelations at Eight Month Lag

| | Autocorrelations | | | | | Z-Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L | I | P | S | Y/$ | L | I | P | S | Y/$ |
| Landings | 0.0262 | 0.0411 | -0.0620 | 0.0500 | 0.0081 | 0.4397 | 0.6835 | -0.4862 | 0.4391 | 0.0550 |
| Imports | -0.0900 | 0.0630 | -0.0877 | -0.1729 | 0.3245 | -1.1606 | 0.6364 | -0.5712 | -1.3705 | 2.1044 |
| Price | -0.2425 | -0.2754 | 0.3366 | -0.5110 | -0.3909 | -2.2589 | -2.2034 | 2.0150 | -2.9704 | -1.7742 |
| Storage | 0.0326 | 0.2156 | 0.4208 | 0.1083 | -0.1380 | 0.3338 | 1.7470 | 2.3870 | 0.8516 | -0.7809 |
| Yen/$ | -0.0110 | 0.1702 | -0.2239 | -0.0691 | 0.6885 | -0.1055 | 1.2087 | -1.3704 | -0.6087 | 3.0973 |

Autocorrelations at Nine Month Lag

| | Autocorrelations | | | | | Z-Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L | I | P | S | Y/$ | L | I | P | S | Y/$ |
| Landings | 0.0223 | 0.0352 | -0.0533 | 0.0496 | 0.0128 | 0.4101 | 0.5964 | -0.4403 | 0.4724 | 0.0895 |
| Imports | -0.0751 | 0.0444 | -0.1012 | -0.1531 | 0.3128 | -1.0249 | 0.4379 | -0.7001 | -1.2821 | 2.0549 |
| Price | -0.2191 | -0.2890 | 0.2522 | -0.4638 | -0.3805 | -2.1598 | -2.4589 | 1.4057 | -2.8460 | -1.7194 |
| Storage | -0.0145 | 0.1784 | 0.4321 | 0.0090 | -0.1409 | -0.1587 | 1.5396 | 2.4768 | 0.0693 | -0.8147 |
| Yen/$ | -0.0105 | 0.1622 | -0.2134 | -0.0659 | 0.6562 | -0.1055 | 1.1791 | -1.3330 | -0.6042 | 2.8958 |

Autocorrelations at Ten Month Lag

| | Autocorrelations | | | | | Z-Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L | I | P | S | Y/$ | L | I | P | S | Y/$ |
| Landings | 0.0204 | 0.0313 | -0.0449 | 0.0486 | 0.0162 | 0.4133 | 0.5375 | -0.3921 | 0.5047 | 0.1168 |
| Imports | -0.0609 | 0.0323 | -0.1128 | -0.1318 | 0.3008 | -0.8839 | 0.3133 | -0.8301 | -1.1721 | 2.0001 |
| Price | -0.1913 | -0.2951 | 0.1749 | -0.4073 | -0.3681 | -1.9984 | -2.6575 | 0.9168 | -2.6383 | -1.6625 |
| Storage | -0.0542 | 0.1377 | 0.4295 | -0.0760 | -0.1436 | -0.6364 | 1.2784 | 2.5300 | -0.5752 | -0.8527 |
| Yen/$ | -0.0100 | 0.1546 | -0.2034 | -0.0628 | 0.6254 | -0.1055 | 1.1504 | -1.2968 | -0.5897 | 2.7197 |

Autocorrelations at Eleven Month Lag

| | Autocorrelations | | | | | Z-Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L | I | P | S | Y/$ | L | I | P | S | Y/$ |
| Landings | 0.0191 | 0.0289 | -0.0369 | 0.0469 | 0.0185 | 0.4312 | 0.5028 | -0.3412 | 0.5297 | 0.1378 |
| Imports | -0.0476 | 0.0251 | -0.1220 | -0.1101 | 0.2886 | -0.7389 | 0.2416 | -0.9570 | -1.0418 | 1.9431 |
| Price | -0.1607 | -0.2940 | 0.1061 | -0.3446 | -0.3541 | -1.7793 | -2.7903 | 0.5284 | -2.3432 | -1.6046 |
| Storage | -0.0863 | 0.0960 | 0.4149 | -0.1460 | -0.1457 | -1.0761 | 0.9644 | 2.5452 | -1.1009 | -0.8942 |
| Yen/$ | -0.0095 | 0.1473 | -0.1939 | -0.0599 | 0.5961 | -0.1054 | 1.1225 | -1.2619 | -0.5950 | 2.5640 |

Autocorrelations at Twelve Month Lag

| | Autocorrelations | | | | | Z-Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L | I | P | S | Y/$ | L | I | P | S | Y/$ |
| Landings | 0.0180 | 0.0274 | -0.0292 | 0.0442 | 0.0200 | 0.4498 | 0.4857 | -0.2877 | 0.5422 | 0.1537 |
| Imports | -0.0354 | 0.0216 | -0.1288 | -0.0887 | 0.2767 | -0.5897 | 0.2087 | -1.0767 | -0.8938 | 1.8862 |
| Price | -0.1288 | -0.2864 | 0.0465 | -0.2787 | -0.3390 | -1.5089 | -2.8545 | 0.2228 | -1.9720 | -1.5464 |
| Storage | -0.1107 | 0.0552 | 0.3905 | -0.2007 | -0.1472 | -1.4539 | 0.6013 | 2.5146 | -1.5213 | -0.9388 |
| Yen/$ | -0.0091 | 0.1404 | -0.1848 | -0.0571 | 0.5682 | -0.1054 | 1.0956 | -1.2282 | -0.5903 | 2.4250 |

Autocorrelations at Thirteen Month Lag

| | Autocorrelations | | | | | Z-Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L | I | P | S | Y/$ | L | I | P | S | Y/$ |
| Landings | 0.0166 | 0.0263 | -0.0220 | 0.0406 | 0.0207 | 0.4582 | 0.4793 | -0.2320 | 0.5389 | 0.1653 |
| Imports | -0.0244 | 0.0208 | -0.1330 | -0.0684 | 0.2652 | -0.4367 | 0.2040 | -1.1855 | -0.7323 | 1.8307 |
| Price | -0.0969 | -0.2730 | -0.0033 | -0.2122 | -0.3232 | -1.1962 | -2.8510 | -0.0156 | -1.5482 | -1.4885 |
| Storage | -0.1276 | 0.0167 | 0.3583 | -0.2406 | -0.1481 | -1.7509 | 0.1972 | 2.4293 | -1.8444 | -0.9854 |
| Yen/$ | -0.0087 | 0.1338 | -0.1761 | -0.0544 | 0.5415 | -0.1054 | 1.0696 | -1.1958 | -0.5855 | 2.2999 |

Autocorrelations at Fourteen Month Lag

| | Autocorrelations | | | | | Z-Values | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L | I | P | S | Y/$ | L | I | P | S | Y/$ |
| Landings | 0.0150 | 0.0255 | -0.0154 | 0.0362 | 0.0210 | 0.4488 | 0.4780 | -0.1746 | 0.5183 | 0.1734 |
| Imports | -0.0147 | 0.0220 | -0.1348 | -0.0495 | 0.2541 | -0.2818 | 0.2209 | -1.2800 | -0.5628 | 1.7775 |
| Price | -0.0660 | -0.2549 | -0.0433 | -0.1475 | -0.3068 | -0.8543 | -2.7822 | -0.1994 | -1.1000 | -1.4312 |
| Storage | -0.1378 | -0.0183 | 0.3203 | -0.2664 | -0.1483 | -1.9583 | -0.2330 | 2.2835 | -2.0728 | -1.0333 |
| Yen/$ | -0.0083 | 0.1276 | -0.1678 | -0.0518 | 0.5161 | -0.1054 | 1.0445 | -1.1646 | -0.5807 | 2.1866 |

# APPENDIX E
# PREDICTION EXPERIMENT RESULTS

## VAR PREDICTION RESULTS

Percent Difference Between Actual and Extended Prediction Values

| Months | Landings | Imports | Prices | Storage | Yen/$ |
|---|---|---|---|---|---|
| 1 | -14.3218 | 27.3156 | -4.9460 | -13.3214 | -6.8184 |
| 2 | 7.0365 | 18.6300 | -6.5962 | -8.8861 | -5.9142 |
| 3 | 13.5986 | 26.8539 | -12.1888 | -4.5189 | -7.9876 |
| 4 | 13.2037 | 11.5016 | -20.7262 | 0.7256 | -3.0087 |
| 5 | -13.0418 | 28.0240 | -18.0781 | -3.2675 | -2.7073 |
| 6 | 8.3129 | 23.6584 | -15.6121 | -76.1413 | -9.6282 |

Percent Difference Between Actual and Forecast Values with Updating Each Period

| Months | Landings | Imports | Prices | Storage | Yen/$ |
|---|---|---|---|---|---|
| 1 | -14.3218 | 27.3156 | -4.9460 | -13.3214 | -6.8184 |
| 2 | 12.9992 | 2.7385 | -3.2120 | -2.4495 | 1.5802 |
| 3 | 6.6780 | 9.2629 | -6.3962 | -2.7417 | -2.1002 |
| 4 | 1.9467 | -6.8542 | -9.0306 | -1.5948 | 4.7803 |
| 5 | -30.2924 | 17.3227 | -0.9380 | -5.6476 | -0.2445 |
| 6 | 9.2383 | 6.0976 | 0.6648 | -73.4567 | -6.7917 |

Percent Difference Between Actual and Forecast Values with Updating Every Two Periods

| Months | Landings | Imports | Prices | Storage | Yen/$ |
|---|---|---|---|---|---|
| 1 | 7.0365 | 18.6300 | -6.5962 | -8.8861 | -5.9142 |
| 2 | 15.7934 | 11.4014 | -10.5550 | -0.9487 | -0.3096 |
| 3 | 7.1911 | -1.3714 | -15.7191 | -0.9795 | 2.5517 |
| 4 | -28.1522 | 15.2162 | -8.0507 | -8.2430 | 5.0414 |
| 5 | -7.0266 | 15.3803 | 1.1763 | -81.6677 | -7.0803 |

Percent Difference Between Actual and Forecast Values with Updating Every Three Periods

| Months | Landings | Imports | Prices | Storage | Yen/$ |
|---|---|---|---|---|---|
| 1 | 13.5986 | 26.8539 | -12.1888 | -4.5189 | -7.9876 |
| 2 | 13.0868 | 0.0006 | -19.7186 | 1.1579 | 4.2747 |
| 3 | -21.0088 | 19.3743 | -13.8440 | -7.1163 | 2.7930 |
| 4 | -6.0933 | 12.1158 | -5.9235 | -88.7217 | -1.3963 |

## SEM PREDICTION RESULTS

Percent Difference Between Actual and Extended Prediction Values

| Months | Prices | Landings | Imports | Storage |
|---|---|---|---|---|
| 1 | -1.6024 | -15.0490 | 19.2484 | -9.7295 |
| 2 | -5.2378 | -0.4676 | 6.5782 | 6.1059 |
| 3 | -10.8348 | -3.6276 | 11.8822 | 11.7245 |
| 4 | -16.6258 | -7.0866 | -5.8723 | 19.7169 |
| 5 | -17.0081 | -36.7880 | 19.0652 | 25.5270 |
| 6 | -11.8602 | -24.0117 | 12.5029 | 34.3224 |

Percent Difference Between Actual and Forecast Values with Updating Each Period

| Months | Prices | Landings | Imports | Storage |
|---|---|---|---|---|
| 1 | -1.6024 | -15.0490 | 19.2484 | -9.7295 |
| 2 | -1.9275 | 11.6186 | -0.7693 | 3.4292 |
| 3 | -4.0602 | 4.7316 | 6.7888 | 0.6989 |
| 4 | -6.4581 | 3.2246 | -11.4267 | 1.3536 |
| 5 | -0.7758 | -28.5667 | 14.3749 | -3.3139 |
| 6 | 0.9686 | 13.1363 | -0.6053 | -1.2235 |

Percent Difference Between Actual and Forecast
Values with Updating Every Two Periods

| Months | Prices | Landings | Imports | Storage |
|---|---|---|---|---|
| 1 | -3.5894 | 4.9698 | 6.6324 | -3.3414 |
| 2 | -6.4290 | 10.7969 | 6.5607 | 4.2638 |
| 3 | -10.7964 | 5.2979 | -9.1226 | 2.6992 |
| 4 | -5.3669 | -26.1508 | 11.4079 | -3.0003 |
| 5 | 0.4432 | -2.1452 | 5.1038 | -4.2123 |

Percent Difference Between Actual and Forecast
Values with Updating Every Three Periods

| Months | Prices | Landings | Imports | Storage |
|---|---|---|---|---|
| 1 | -1.7563 | 23.5553 | 8.8705 | -34.0386 |
| 2 | -8.8317 | 13.7628 | -8.5935 | -22.6939 |
| 3 | -7.5852 | -18.0859 | 13.0130 | -21.9563 |
| 4 | -4.6574 | 3.6454 | 2.5203 | -22.0589 |

# APPENDIX F
# DATA USED IN THE RESPECIFIED SEM OF THE U.S. SHRIMP MARKET

Description of the Data

Consump. = disappearances from total U.S. cold storage holdings *
source: Dr. John Vondruska, N.M.F.S.

Landings = total U.S. South Atlantic and Gulf of Mexico landings of shrimp *
source: Dr. John Vondruska, N.M.F.S.

Imports = total U.S. imports of fresh and frozen shrimp *
source: Dr. John Vondruska, N.M.F.S.

Price = wholesale price of 26-30 count shrimp at New York ($/lb.)
source: Dr. John Vondruska, N.M.F.S.

Storage = total U.S., end of month, cold storage holdings *
source: Dr. John Vondruska, N.M.F.S.

Yen/$ = Japanese yen/U.S. dollar exchange rate
source: International Financial Statistics, I.M.F., (market rate "ae")

Expend. = expenditures in eating places
source: Monthly Retail Trade, U.S.D.C. (millions of dollars)

Rain = average precipitation in southern Louisiana (inches)
source: Climatological Data, U.S.D.C.

GNP P.D. = Gross National Product Implicit Price Deflator
source: Survey of Current Business, U.S.D.C., converted to monthly data by J.D. Lea

Fuel Index = Producer Price Index, middle distilate, (1967=100)
source: Survey of Current Business, U.S.D.C.

* = 1,000 pounds heads-off basis

| | | | Consump | Landings | Imports | Price | Storage | Yen/$ | Expend. | Rain | GNP P.D. | Fuel Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1972 | 4 | 1 | 20046 | 4661 | 18125 | 2.06 | 62893 | 304.8 | 2129 | 2.32 | 99.42 | 110.5 |
| | 5 | 2 | 28613 | 15119 | 24901 | 2.03 | 61698 | 304.6 | 2306 | 6.48 | 99.70 | 110.5 |
| | 6 | 3 | 30075 | 19143 | 23490 | 1.93 | 64329 | 301.1 | 2406 | 2.14 | 99.97 | 110.7 |
| | 7 | 4 | 31021 | 22140 | 23382 | 1.94 | 66579 | 301.1 | 2449 | 6.87 | 100.25 | 110.7 |
| | 8 | 5 | 18621 | 22525 | 19984 | 1.82 | 71894 | 301.1 | 2499 | 4.35 | 100.68 | 111.9 |
| | 9 | 6 | 33124 | 18477 | 18913 | 1.70 | 89868 | 301.1 | 2305 | 4.93 | 101.11 | 111.9 |
| | 10 | 7 | 33474 | 16340 | 29234 | 1.75 | 89732 | 301.1 | 2280 | 3.88 | 101.54 | 112.9 |
| | 11 | 8 | 27061 | 14086 | 22141 | 1.66 | 95113 | 301.1 | 2175 | 6.99 | 102.01 | 112.9 |
| | 12 | 9 | 26711 | 9235 | 20716 | 1.68 | 97610 | 302.0 | 2282 | 6.73 | 102.48 | 113.9 |

| | | | Consump | Landings | Imports | Price | Storage | Yen/S | Expend. | Rain | GNP P.D. | Fuel Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1973 | 1 | 10 | 28299 | 5618 | 18232 | 1.73 | 95772 | 301.2 | 2117 | 3.91 | 102.95 | 113.9 |
| | 2 | 11 | 18956 | 4170 | 16519 | 1.87 | 85942 | 270.0 | 2046 | 3.42 | 103.55 | 124.1 |
| | 3 | 12 | 24022 | 4335 | 15796 | 1.99 | 81239 | 265.8 | 2343 | 10.13 | 104.15 | 129.1 |
| | 4 | 13 | 25085 | 4041 | 16464 | 2.02 | 71286 | 265.5 | 2348 | 10.43 | 104.75 | 130.1 |
| | 5 | 14 | 23021 | 8667 | 15587 | 2.13 | 62762 | 265.0 | 2590 | 3.66 | 105.34 | 133.8 |
| | 6 | 15 | 23487 | 19682 | 14835 | 2.16 | 57774 | 265.3 | 2689 | 3.38 | 105.94 | 137.4 |
| | 7 | 16 | 26945 | 16298 | 16375 | 2.18 | 56543 | 263.5 | 2712 | 5.48 | 106.53 | 141.8 |
| | 8 | 17 | 30317 | 11693 | 18425 | 2.48 | 56552 | 263.3 | 2907 | 4.86 | 107.27 | 143.3 |
| | 9 | 18 | 20187 | 13779 | 17994 | 2.69 | 51721 | 265.7 | 2696 | 14.35 | 108.00 | 145.6 |
| | 10 | 19 | 29238 | 17039 | 29543 | 2.61 | 58194 | 266.8 | 2690 | 4.47 | 108.74 | 147.7 |
| | 11 | 20 | 22474 | 13591 | 24572 | 2.68 | 68995 | 280.0 | 2573 | 4.58 | 109.40 | 157.3 |
| | 12 | 21 | 18353 | 11682 | 20363 | 2.74 | 77790 | 280.0 | 2618 | 6.13 | 110.06 | 171.7 |
| 1974 | 1 | 22 | 27595 | 8215 | 28269 | 2.64 | 83967 | 299.0 | 2400 | 8.52 | 110.72 | 194.8 |
| | 2 | 23 | 25938 | 5766 | 22878 | 2.48 | 87815 | 287.6 | 2287 | 2.87 | 111.64 | 234.1 |
| | 3 | 24 | 17475 | 4505 | 19488 | 2.38 | 84894 | 276.0 | 2608 | 4.92 | 112.56 | 251.8 |
| | 4 | 25 | 22110 | 3868 | 16879 | 2.30 | 85630 | 279.8 | 2673 | 5.11 | 113.48 | 257.9 |
| | 5 | 26 | 31033 | 11404 | 20145 | 2.33 | 82298 | 281.9 | 2958 | 6.32 | 114.46 | 269.2 |
| | 6 | 27 | 24286 | 15463 | 18138 | 2.30 | 75772 | 284.1 | 3043 | 3.31 | 115.44 | 279.7 |
| | 7 | 28 | 31182 | 17206 | 16608 | 2.16 | 74933 | 297.8 | 3078 | 5.21 | 116.42 | 288.9 |
| | 8 | 29 | 31759 | 17270 | 17632 | 1.86 | 71148 | 302.7 | 3260 | 7.16 | 117.54 | 294.8 |
| | 9 | 30 | 26685 | 12975 | 19073 | 1.65 | 68885 | 298.5 | 3316 | 5.07 | 118.67 | 298.8 |
| | 10 | 31 | 33245 | 14448 | 27034 | 1.76 | 71806 | 299.9 | 3374 | 1.70 | 119.79 | 297.9 |
| | 11 | 32 | 26332 | 13995 | 27182 | 1.74 | 74948 | 300.1 | 3219 | 5.99 | 120.82 | 296.0 |
| | 12 | 33 | 26895 | 9172 | 21795 | 1.74 | 80986 | 301.0 | 3241 | 5.11 | 121.85 | 300.1 |
| 1975 | 1 | 34 | 30159 | 5116 | 22973 | 1.81 | 81020 | 297.9 | 3100 | 4.69 | 122.88 | 299.1 |
| | 2 | 35 | 22379 | 4416 | 15411 | 1.95 | 75264 | 286.6 | 2948 | 1.79 | 123.40 | 297.5 |
| | 3 | 36 | 23605 | 4090 | 14355 | 2.19 | 70373 | 293.8 | 3304 | 4.31 | 123.92 | 294.6 |
| | 4 | 37 | 23310 | 3506 | 13566 | 2.44 | 60776 | 293.3 | 3460 | 5.05 | 124.44 | 294.9 |
| | 5 | 38 | 26204 | 11477 | 14228 | 2.88 | 52543 | 291.4 | 3963 | 9.27 | 125.19 | 296.1 |
| | 6 | 39 | 27904 | 15123 | 18844 | 2.86 | 47084 | 296.4 | 4004 | 8.60 | 125.93 | 301.3 |
| | 7 | 40 | 29556 | 15706 | 18560 | 2.73 | 47992 | 297.4 | 3992 | 10.46 | 126.68 | 308.3 |
| | 8 | 41 | 28706 | 12142 | 16459 | 2.88 | 48656 | 298.0 | 4177 | 9.63 | 127.45 | 312.9 |
| | 9 | 42 | 28656 | 11558 | 20504 | 2.89 | 46744 | 302.7 | 3732 | 4.39 | 128.22 | 318.2 |
| | 10 | 43 | 31691 | 13789 | 26383 | 3.01 | 47637 | 301.8 | 3931 | 3.06 | 128.99 | 322.9 |
| | 11 | 44 | 25552 | 15495 | 25054 | 3.15 | 52843 | 303.0 | 3741 | 3.80 | 129.37 | 330.8 |
| | 12 | 45 | 28592 | 10648 | 22362 | 3.29 | 59502 | 305.2 | 3822 | 3.54 | 129.74 | 336.3 |
| 1976 | 1 | 46 | 29872 | 5378 | 21922 | 3.50 | 55889 | 303.7 | 3626 | 2.08 | 130.12 | 336.7 |
| | 2 | 47 | 23199 | 4340 | 17246 | 3.79 | 50417 | 302.3 | 3471 | 2.87 | 130.51 | 339.3 |
| | 3 | 48 | 21398 | 4197 | 21948 | 3.82 | 46085 | 299.7 | 3785 | 5.04 | 130.91 | 335.3 |
| | 4 | 49 | 25634 | 4444 | 19920 | 4.12 | 48198 | 299.4 | 3996 | 0.82 | 131.30 | 331.8 |
| | 5 | 50 | 27930 | 16470 | 18227 | 4.43 | 44274 | 300.0 | 4446 | 5.03 | 131.83 | 328.5 |
| | 6 | 51 | 29259 | 22953 | 23073 | 4.30 | 43361 | 297.4 | 4434 | 3.78 | 132.36 | 329.2 |
| | 7 | 52 | 33344 | 21216 | 22403 | 3.83 | 49714 | 293.4 | 4668 | 5.11 | 132.89 | 332.2 |
| | 8 | 53 | 25422 | 16547 | 18182 | 3.18 | 54372 | 288.8 | 4679 | 3.10 | 133.59 | 336.2 |
| | 9 | 54 | 30217 | 18898 | 18343 | 3.43 | 59635 | 287.5 | 4347 | 3.87 | 134.29 | 338.9 |
| | 10 | 55 | 31357 | 17034 | 24302 | 3.33 | 63755 | 293.7 | 4360 | 4.21 | 134.99 | 341.2 |
| | 11 | 56 | 24074 | 11347 | 31343 | 3.68 | 69097 | 295.8 | 3978 | 6.00 | 135.59 | 344.3 |
| | 12 | 57 | 37044 | 5999 | 29067 | 3.85 | 79986 | 293.0 | 4227 | 8.11 | 136.20 | 349.8 |

| | | | Consump | Landings | Imports | Price | Storege | Yen/$ | Expend. | Rein | GNP P.D. | Fuel Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1977 | 1 | 58 | 20398 | 2034 | 22024 | 3.91 | 72863 | 289.3 | 3820 | 5.73 | 136.80 | 359.2 |
| | 2 | 59 | 28613 | 3596 | 19832 | 3.98 | 73843 | 282.7 | 3831 | 2.25 | 137.54 | 369.6 |
| | 3 | 60 | 28870 | 2586 | 25793 | 4.04 | 66450 | 277.5 | 4296 | 3.67 | 138.27 | 378.0 |
| | 4 | 61 | 24852 | 5425 | 21477 | 3.96 | 63679 | 277.7 | 4550 | 6.47 | 139.01 | 384.4 |
| | 5 | 62 | 25232 | 19768 | 21006 | 3.83 | 63343 | 277.3 | 4949 | 2.19 | 139.68 | 387.5 |
| | 6 | 63 | 34112 | 26988 | 24582 | 3.76 | 67768 | 267.7 | 5007 | 2.98 | 140.36 | 387.5 |
| | 7 | 64 | 32928 | 23203 | 20690 | 3.61 | 72437 | 266.0 | 5150 | 5.91 | 141.03 | 388.6 |
| | 8 | 65 | 35770 | 24421 | 20962 | 3.15 | 77873 | 267.3 | 5163 | 12.17 | 141.77 | 389.1 |
| | 9 | 66 | 25360 | 20390 | 16822 | 3.17 | 82152 | 265.5 | 4756 | 7.69 | 142.50 | 389.3 |
| | 10 | 67 | 34168 | 20402 | 23835 | 3.14 | 88801 | 250.6 | 4768 | 4.93 | 143.24 | 389.6 |
| | 11 | 68 | 28207 | 17251 | 22773 | 3.36 | 92657 | 247.0 | 4551 | 9.50 | 143.87 | 392.4 |
| | 12 | 69 | 33842 | 12170 | 24958 | 3.22 | 95931 | 240.0 | 4740 | 4.16 | 144.49 | 394.4 |
| 1978 | 1 | 70 | 23335 | 6708 | 19170 | 3.30 | 94213 | 241.4 | 4199 | 9.78 | 145.12 | 396.7 |
| | 2 | 71 | 34053 | 4204 | 20889 | 3.35 | 92371 | 238.7 | 4127 | 2.55 | 146.38 | 398.6 |
| | 3 | 72 | 29418 | 4763 | 23995 | 3.27 | 77474 | 222.4 | 4948 | 3.04 | 147.63 | 394.8 |
| | 4 | 73 | 21342 | 5391 | 17002 | 3.40 | 70745 | 222.9 | 5126 | 2.97 | 148.89 | 393.3 |
| | 5 | 74 | 33673 | 16731 | 19152 | 3.48 | 66290 | 223.4 | 5447 | 4.74 | 149.93 | 393.3 |
| | 6 | 75 | 32341 | 25639 | 18773 | 3.48 | 58723 | 204.7 | 5660 | 7.77 | 150.98 | 393.3 |
| | 7 | 76 | 34265 | 21931 | 19405 | 3.51 | 58714 | 190.7 | 5843 | 7.33 | 152.02 | 393.2 |
| | 8 | 77 | 30623 | 19373 | 13793 | 3.68 | 60489 | 190.2 | 5980 | 8.18 | 153.14 | 393.6 |
| | 9 | 78 | 32107 | 16627 | 18872 | 3.99 | 59068 | 189.2 | 5614 | 3.76 | 154.26 | 394.0 |
| | 10 | 79 | 34405 | 18520 | 23314 | 3.94 | 58937 | 176.0 | 5528 | 0.17 | 155.38 | 400.1 |
| | 11 | 80 | 24092 | 16773 | 21480 | 4.27 | 61240 | 197.5 | 5315 | 5.52 | 156.45 | 407.6 |
| | 12 | 81 | 26030 | 10815 | 17662 | 4.32 | 68196 | 194.6 | 5667 | 3.17 | 157.53 | 418.0 |
| 1979 | 1 | 82 | 21790 | 5331 | 14680 | 4.54 | 64772 | 201.3 | 4957 | 6.42 | 158.60 | 425.7 |
| | 2 | 83 | 24113 | 4776 | 15441 | 4.83 | 59134 | 202.2 | 4959 | 9.72 | 159.68 | 432.6 |
| | 3 | 84 | 24335 | 4228 | 15709 | 5.06 | 51355 | 209.3 | 6015 | 3.99 | 160.77 | 451.9 |
| | 4 | 85 | 26776 | 4245 | 21133 | 5.21 | 43415 | 221.8 | 5915 | 9.08 | 161.85 | 477.9 |
| | 5 | 86 | 34853 | 15408 | 21772 | 5.63 | 38219 | 219.8 | 6179 | 7.44 | 162.94 | 504.8 |
| | 6 | 87 | 35205 | 22658 | 27451 | 5.93 | 34672 | 217.0 | 6397 | 1.73 | 164.03 | 542.3 |
| | 7 | 88 | 24787 | 16312 | 22451 | 5.84 | 42686 | 217.2 | 6443 | 11.30 | 165.12 | 593.1 |
| | 8 | 89 | 33803 | 18707 | 23975 | 5.74 | 53052 | 220.0 | 6746 | 5.16 | 166.10 | 632.8 |
| | 9 | 90 | 29963 | 11712 | 24325 | 5.65 | 56651 | 223.3 | 6234 | 6.48 | 167.07 | 680.6 |
| | 10 | 91 | 27427 | 18972 | 26418 | 5.66 | 59712 | 237.7 | 6257 | 2.12 | 168.05 | 709.9 |
| | 11 | 92 | 26249 | 15471 | 25974 | 5.58 | 72956 | 248.8 | 6161 | 4.40 | 169.35 | 715.3 |
| | 12 | 93 | 21767 | 10242 | 19093 | 5.51 | 83260 | 239.7 | 6472 | 3.34 | 170.64 | 719.9 |
| 1980 | 1 | 94 | 26556 | 5231 | 19088 | 5.46 | 87443 | 238.8 | 5874 | 6.70 | 171.94 | 739.3 |
| | 2 | 95 | 22569 | 3174 | 17632 | 5.31 | 82681 | 249.8 | 5707 | 1.73 | 173.45 | 793.5 |
| | 3 | 96 | 27426 | 2385 | 17582 | 4.99 | 78641 | 249.7 | 6353 | 9.38 | 174.95 | 837.7 |
| | 4 | 97 | 17526 | 2656 | 14610 | 4.48 | 68904 | 239.0 | 6465 | 10.49 | 176.46 | 858.9 |
| | 5 | 98 | 34551 | 9439 | 16712 | 4.25 | 66818 | 224.3 | 6878 | 11.13 | 177.72 | 864.8 |
| | 6 | 99 | 32610 | 19852 | 17818 | 4.35 | 54012 | 217.6 | 6882 | 2.41 | 178.98 | 860.9 |
| | 7 | 100 | 28290 | 17978 | 18522 | 4.56 | 48245 | 227.0 | 7039 | 5.03 | 180.24 | 870.2 |
| | 8 | 101 | 31585 | 20092 | 14436 | 4.61 | 52722 | 219.0 | 7318 | 2.66 | 181.87 | 875.6 |
| | 9 | 102 | 36547 | 21215 | 23598 | 4.44 | 51869 | 212.2 | 6720 | 5.34 | 183.50 | 873.7 |
| | 10 | 103 | 37393 | 23715 | 30146 | 4.25 | 56503 | 211.5 | 6883 | 5.06 | 185.13 | 868.4 |
| | 11 | 104 | 28622 | 14260 | 29188 | 4.23 | 67001 | 216.7 | 6509 | 4.62 | 186.76 | 873.4 |
| | 12 | 105 | 34951 | 12037 | 28086 | 4.25 | 77226 | 203.0 | 6850 | 1.79 | 188.38 | 891.1 |

| | | | Consump | Landings | Imports | Price | Storage | Yen/$ | Expend. | Rain | GNP P.D. | Fuel Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1981 | 1 | 106 | 24449 | 4525 | 25364 | 4.40 | 77678 | 204.7 | 6454 | 1.58 | 190.01 | 935.4 |
| | 2 | 107 | 26308 | 2138 | 13643 | 4.64 | 79129 | 208.8 | 6150 | 6.00 | 191.02 | 1000.3 |
| | 3 | 108 | 27791 | 3868 | 21991 | 4.75 | 65952 | 211.0 | 7099 | 1.81 | 192.02 | 1082.8 |
| | 4 | 109 | 33455 | 4803 | 19009 | 4.83 | 60936 | 215.0 | 7267 | 1.09 | 193.03 | 1105.4 |
| | 5 | 110 | 41064 | 20363 | 20199 | 4.90 | 49179 | 224.1 | 7634 | 4.34 | 194.59 | 1092.5 |
| | 6 | 111 | 36219 | 27853 | 20228 | 4.79 | 46050 | 225.8 | 7603 | 3.35 | 196.14 | 1092.2 |
| | 7 | 112 | 36784 | 25424 | 20387 | 4.21 | 47558 | 239.5 | 7798 | 6.18 | 197.70 | 1079.8 |
| | 8 | 113 | 39351 | 24961 | 20310 | 3.55 | 53214 | 228.0 | 7872 | 4.88 | 199.03 | 1076.7 |
| | 9 | 114 | 29486 | 18083 | 16939 | 3.84 | 55740 | 232.7 | 7355 | 3.55 | 200.36 | 1067.8 |
| | 10 | 115 | 34744 | 20515 | 21305 | 4.05 | 58226 | 233.8 | 7524 | 3.18 | 201.69 | 1056.1 |
| | 11 | 116 | 34684 | 17460 | 25083 | 4.49 | 61484 | 214.3 | 6902 | 2.14 | 202.45 | 1047.5 |
| | 12 | 117 | 28764 | 10823 | 23603 | 4.48 | 63361 | 219.9 | 7193 | 5.24 | 203.22 | 1060.6 |
| 1982 | 1 | 118 | 29638 | 5108 | 21581 | 4.78 | 64871 | 230.5 | 6562 | 2.78 | 203.98 | 1067.8 |
| | 2 | 119 | 24555 | 3547 | 13697 | 5.41 | 58437 | 237.0 | 6528 | 5.73 | 204.91 | 1058.2 |
| | 3 | 120 | 22790 | 3147 | 20404 | 5.93 | 48054 | 246.5 | 7370 | 2.75 | 205.84 | 1029.3 |
| | 4 | 121 | 20587 | 3073 | 18578 | 6.16 | 46892 | 236.1 | 7676 | 5.71 | 206.77 | 953.6 |
| | 5 | 122 | 49097 | 17366 | 26275 | 6.33 | 46036 | 242.4 | 8039 | 4.10 | 207.36 | 928.7 |
| | 6 | 123 | 41322 | 24304 | 27418 | 6.22 | 36435 | 254.0 | 8093 | 5.24 | 207.94 | 974.6 |
| | 7 | 124 | 33317 | 20233 | 18841 | 5.79 | 39826 | 257.5 | 8517 | 6.13 | 208.53 | 1024.0 |
| | 8 | 125 | 45514 | 15959 | 29985 | 6.19 | 41575 | 261.7 | 8519 | 6.17 | 209.11 | 1022.2 |
| | 9 | 126 | 38048 | 14999 | 26185 | 6.57 | 40026 | 269.5 | 7955 | 5.83 | 209.69 | 998.8 |
| | 10 | 127 | 36411 | 18256 | 26572 | 6.43 | 41143 | 277.3 | 8257 | 3.40 | 210.27 | 999.2 |
| | 11 | 128 | 42582 | 14577 | 38010 | 6.65 | 46317 | 253.1 | 7653 | 5.24 | 211.14 | 1041.5 |
| | 12 | 129 | 37263 | 8659 | 38605 | 4.48 | 51478 | 235.0 | 8127 | 12.03 | 212.00 | 1054.5 |
| 1983 | 1 | 130 | 34859 | 5213 | 32305 | 6.64 | 57552 | 237.9 | 7499 | 5.65 | 212.87 | 985.3 |
| | 2 | 131 | 25438 | 3049 | 21408 | 6.52 | 56668 | 235.5 | 7292 | 7.51 | 213.33 | 927.4 |
| | 3 | 132 | 31617 | 2694 | 24999 | 6.25 | 53032 | 239.4 | 8397 | 4.62 | 213.79 | 874.2 |
| | 4 | 133 | 30396 | 3503 | 22801 | 6.08 | 45723 | 237.0 | 8600 | 6.58 | 214.25 | 813.4 |
| | 5 | 134 | 40747 | 11619 | 28604 | 6.10 | 39525 | 238.3 | 8907 | 6.34 | 214.80 | 838.1 |
| | 6 | 135 | 39266 | 23889 | 26229 | 6.24 | 36076 | 239.7 | 9084 | 8.43 | 215.34 | 879.4 |
| | 7 | 136 | 39811 | 19870 | 29270 | 5.95 | 39074 | 241.7 | 9511 | 3.60 | 215.89 | 876.3 |
| | 8 | 137 | 44402 | 16855 | 37754 | 5.78 | 44787 | 246.6 | 9429 | 8.35 | 216.66 | 883.0 |
| | 9 | 138 | 41087 | 14949 | 35823 | 5.72 | 52234 | 236.1 | 8940 | 7.15 | 217.44 | 894.3 |
| | 10 | 139 | 55143 | 17710 | 44485 | 5.59 | 59662 | 233.7 | 9071 | 2.12 | 218.21 | 912.2 |
| | 11 | 140 | 50601 | 14403 | 43539 | 5.55 | 62188 | 234.0 | 8494 | 4.41 | 219.00 | 901.8 |
| | 12 | 141 | 43348 | 9426 | 40757 | 5.46 | 66605 | 232.2 | 8691 | 5.93 | 219.79 | 892.1 |
| 1984 | 1 | 142 | 34407 | 4191 | 35780 | 5.41 | 70662 | 234.8 | 8264 | 4.60 | 220.58 | 871.4 |
| | 2 | 143 | 36506 | 2999 | 26359 | 5.48 | 75741 | 233.5 | 8293 | 5.21 | 221.19 | 924.4 |
| | 3 | 144 | 36930 | 2877 | 28892 | 5.66 | 67221 | 224.7 | 9183 | 2.93 | 221.79 | 952.1 |
| | 4 | 145 | 39438 | 3510 | 27053 | 5.68 | 60638 | 226.0 | 9277 | 1.41 | 222.40 | 874.9 |
| | 5 | 146 | 36426 | 17090 | 26055 | 5.45 | 49433 | 231.5 | 9706 | 5.74 | 223.12 | 881.9 |
| | 6 | 147 | 53264 | 29668 | 28287 | 5.35 | 52166 | 237.5 | 9994 | 6.11 | 223.85 | 895.2 |
| | 7 | 148 | 55248 | 24977 | 38635 | 5.20 | 49766 | 245.5 | 10151 | 6.77 | 224.57 | 893.4 |
| | 8 | 149 | 47072 | 20375 | 28214 | 4.90 | 54962 | 241.3 | 10585 | 7.36 | 225.08 | 859.6 |
| | 9 | 150 | 40849 | 14899 | 32224 | 4.75 | 54463 | 245.5 | 9658 | 3.86 | 225.59 | 837.8 |
| | 10 | 151 | 63823 | 20429 | 45170 | 5.07 | 58852 | 245.3 | 9414 | 9.23 | 226.10 | 854.4 |
| | 11 | 152 | 43555 | 20980 | 37078 | 5.03 | 58393 | 246.3 | 9266 | 2.80 | 226.76 | 868.9 |
| | 12 | 153 | 49752 | 12111 | 31365 | 4.87 | 70378 | 251.1 | 9709 | 3.20 | 227.42 | 851.4 |

| | | | Consump | Landings | Imports | Price | Storage | Yen/$ | Expend. | Rain | GNP P.D. | Fuel Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | 1 | 154 | 37203 | 8710 | 31077 | 4.99 | 61051 | 254.7 | 8724 | 5.24 | 228.08 | 835.7 |
| | 2 | 155 | 33975 | 4104 | 27629 | 5.10 | 60742 | 259.5 | 8542 | 5.80 | 228.70 | 810.3 |
| | 3 | 156 | 46824 | 3866 | 36879 | 4.85 | 55851 | 252.5 | 9938 | 5.02 | 229.32 | 809.9 |
| | 4 | 157 | 37932 | 4667 | 30723 | 4.62 | 48133 | 252.3 | 9836 | 1.68 | 229.94 | 820.3 |
| | 5 | 158 | 51342 | 23148 | 32602 | 4.61 | 43339 | 251.9 | 10661 | 2.65 | 230.28 | 851.0 |
| | 6 | 159 | 54682 | 28346 | 33906 | 4.62 | 44027 | 249.0 | 10634 | 3.56 | 230.62 | 797.7 |
| | 7 | 160 | 48810 | 25919 | 31312 | 4.59 | 47302 | 236.7 | 10755 | 7.44 | 230.97 | 754.9 |
| | 8 | 161 | 51414 | 20901 | 29808 | 4.63 | 51914 | 237.3 | 10791 | 8.09 | 231.66 | 743.6 |
| | 9 | 162 | 45398 | 15938 | 34924 | 4.65 | 49747 | 217.0 | 10403 | 6.01 | 232.35 | 800.5 |
| | 10 | 163 | 51099 | 19716 | 33135 | 4.70 | 53368 | 211.5 | 10453 | 13.37 | 233.03 | 841.3 |
| | 11 | 164 | 60522 | 16238 | 52271 | 4.78 | 53547 | 202.0 | 10134 | 1.75 | 233.52 | 887.5 |
| | 12 | 165 | 45296 | 15790 | 35208 | 4.98 | 59308 | 200.5 | 10268 | 4.66 | 234.00 | 905.3 |
| 1986 | 1 | 166 | 48566 | 8731 | 35425 | 5.09 | 61614 | 191.8 | 9993 | 3.11 | 234.48 | 830.2 |
| | 2 | 167 | 33536 | 4847 | 25439 | 5.40 | 55301 | 179.7 | 10040 | 3.09 | 234.83 | 631.6 |
| | 3 | 168 | 40861 | 5420 | 29042 | 5.63 | 49448 | 179.6 | 10651 | 2.36 | 235.17 | 519.1 |
| | 4 | 169 | 43345 | 5348 | 33635 | 5.82 | 41099 | 168.3 | 11714 | 2.07 | 235.51 | 504.3 |
| | 5 | 170 | 62079 | 26059 | 36730 | 6.30 | 35184 | 171.8 | 11020 | 4.36 | 236.20 | 476.4 |
| | 6 | 171 | 53949 | 27829 | 35330 | 6.45 | 31461 | 165.0 | 11114 | 6.79 | 236.89 | 452.9 |
| | 7 | 172 | 62945 | 21808 | 44488 | 6.22 | 35281 | 154.3 | 11438 | 5.49 | 237.58 | 369.0 |
| | 8 | 173 | 55509 | 24115 | 37840 | 6.05 | 36600 | 156.1 | 11503 | 4.85 | 237.79 | 406.5 |
| | 9 | 174 | 55798 | 22568 | 41747 | 5.89 | 41360 | 153.6 | 11168 | 4.42 | 237.99 | 469.0 |
| | 10 | 175 | 55063 | 25162 | 40232 | 5.55 | 47408 | 161.5 | 11753 | 4.35 | 238.20 | 436.0 |
| | 11 | 176 | 59813 | 16408 | 50678 | 5.82 | 55310 | 162.4 | 10919 | 6.68 | 238.41 | 440.7 |
| | 12 | 177 | 54006 | 14985 | 41735 | 5.86 | 60280 | 152.5 | 11478 | 6.34 | 238.62 | 461.8 |
| Average of Columns | | | | | | | | | | | | |
| | | | 33585.50 | 13346.07 | 24681.25 | 4.18 | 61089.63 | 247.81 | 6234.73 | 5.20 | 169.95 | 577.01 |

Average of Transformed Data 1972:4 thru 1986:6 (used in the calculation of elasticities)

| | | | Consump | Landings | Imports | Price | Storage | Yen/$ | Expend. | Rain | GNP P.D. | Fuel Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 37.3508 | 13.085 | 61.4072 | 2.4359 | 61.7891 | 251.6696 | 3.4274 | | | |

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# BIOGRAPHICAL SKETCH

John Dale "Zach" Lea was born to Robert L. "Larry" and Luana Townsend Lea on October 11, 1947. Dale grew up in Zachary, Louisiana, sharing life and chores on the family's small farm with his brother, Robert. Dale was active in Boy Scouts, achieving the rank of Eagle. In high school he was active in student government and in the high school band where he served as band captain during his senior year. After graduating from Zachary High School in 1965, Dale attended Louisiana State University (LSU) where he received the Bachelor of Science degree in zoology in 1969. At LSU Dale also received the nickname "Zach" and met his future wife, Marion Shattuck Wilson.

After graduation from LSU, Zach embarked on a career in public service. His first assignment was with the U.S. Peace Corps as a fish aquaculturist in Rajasthan, India. After India, he returned to LSU for his master's degree in agricultural economics, which he received in late 1974. While working on his master's degree, he married Marion and adopted her four-year-old-son, Christopher. After receiving his master's degree, Zach worked for the University of Maryland as a Sea Grant Advisory Agent teaching business record keeping practices to Chesapeake Bay fishermen. Marion and Zach had their second child, Georgia, while they were in Maryland.

Finding life in the Washington, D.C., area too expensive for his taste and budget, Zach moved the family to the Mississippi Gulf Coast, where he worked as the Marine Economics Advisory Specialist with Mississippi State University's Sea Grant program. Marion and Zach's third child, Margaret, was born while the family lived in Long Beach, Mississippi. After five years in the same job, Zach attempted to go into the oyster business for himself but failed due to a lack of resources. Another incentive to quit the oyster business was an opportunity to return to international development work.

In 1981, Zach accepted a position with Experience, Inc., as the Data Management Advisor on a USAID development project in Sudan. In Sudan, he enjoyed conducting surveys to document the labor use patterns of Sudanese farmers as they produced sorghum and sesame with traditional hand-tool technology. The Lea family enjoyed life in the small village of Damazin, where a typical weekend included a swim in the Blue Nile river.

In 1984, Zach returned to the U.S. to begin his studies for the Ph.D. at the University of Florida.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

J. Scott Shonkwiler, Chairman
Associate Professor of Food and Resource Economics

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

G. S. Maddala
Graduate Research Professor of Economics

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

James C. Cato

James C. Cato
Professor of Food and Resource Economics

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Richard L Kilmer

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Associate Professor of Food and Resource Economics

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This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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